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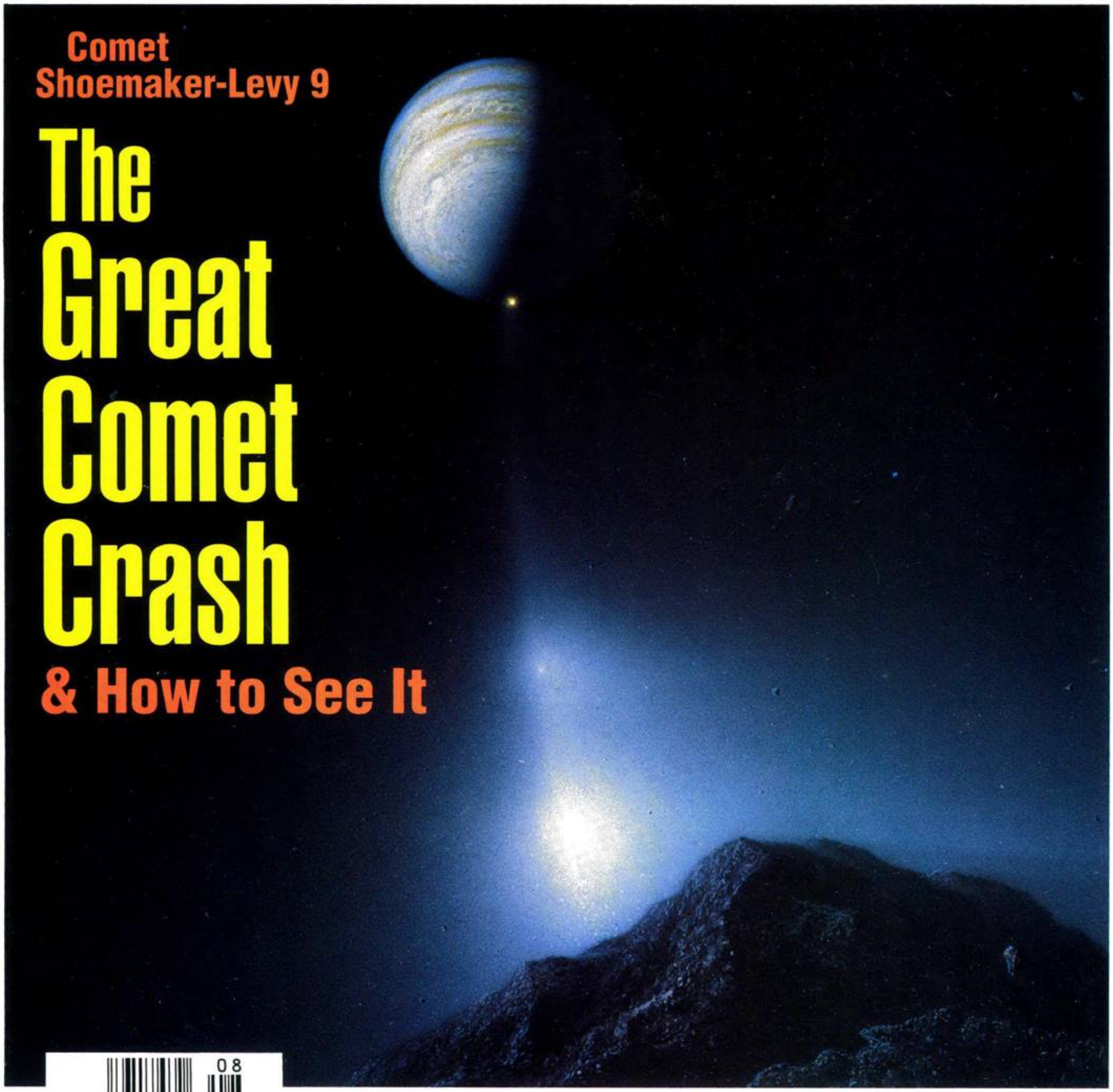
Interlopers from the Edge of the Solar System



Comet Shoemaker-Levy 9

The Great Comet Crash

& How to See It

- Hi-Power Images from a Digital Darkroom
- Will Perseid Meteors "Storm" This Year?

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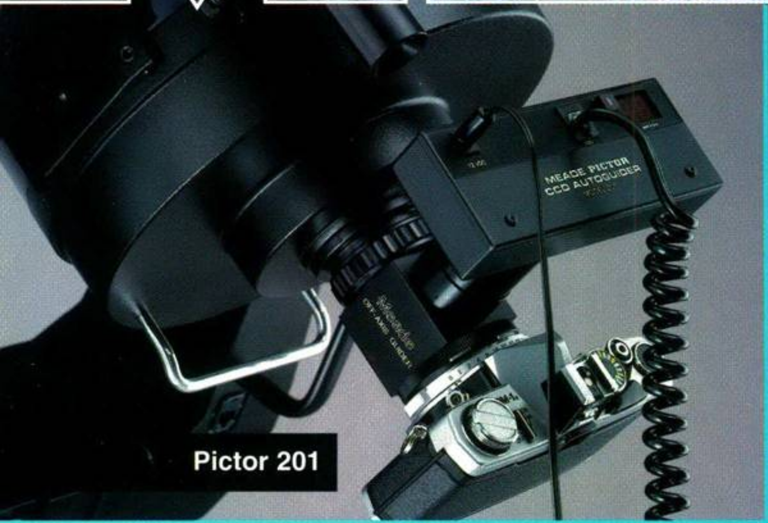
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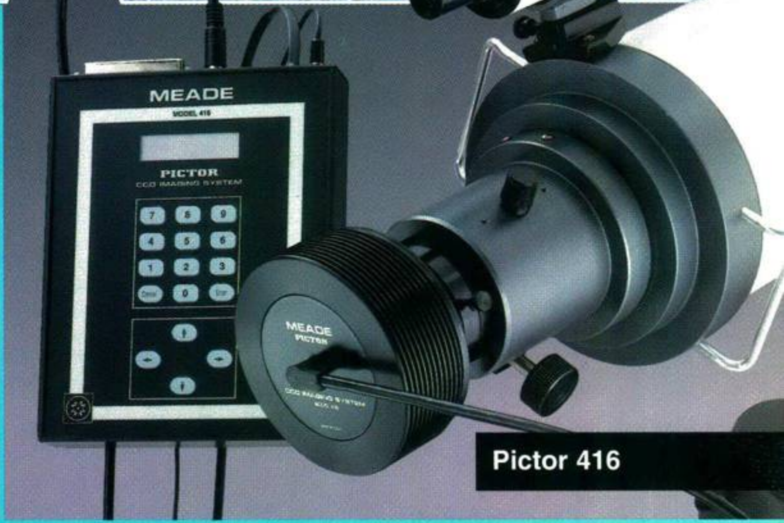
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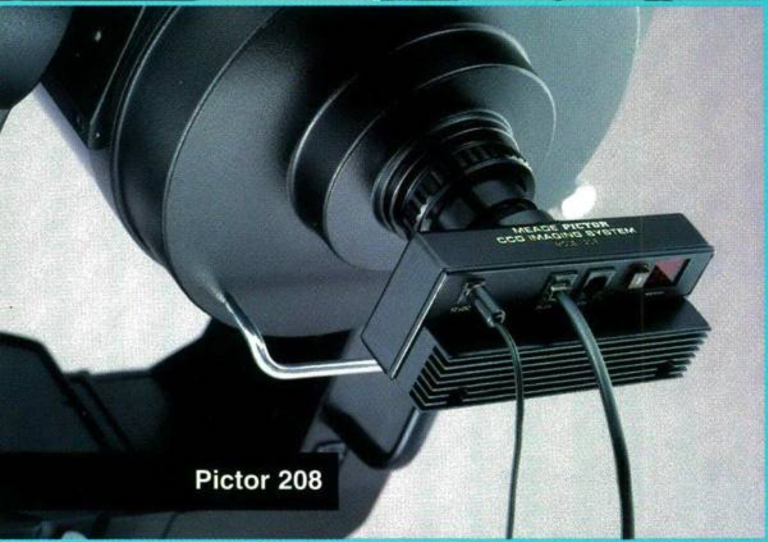
Pictor 416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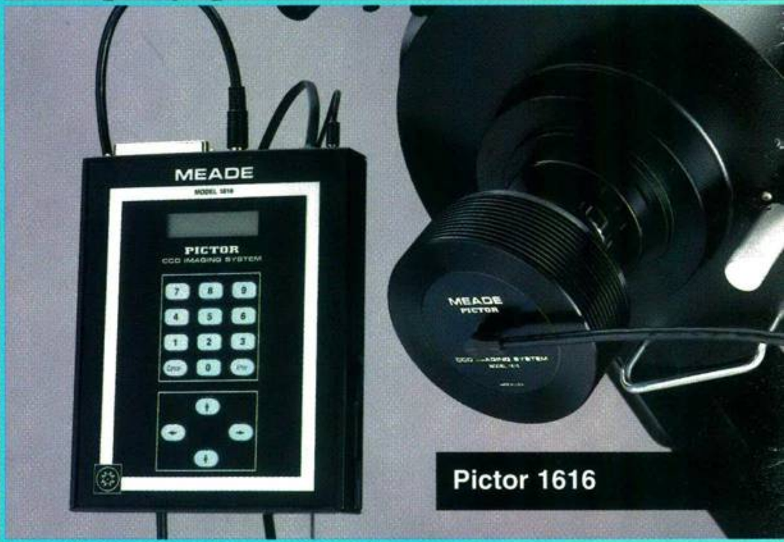
Pictor 208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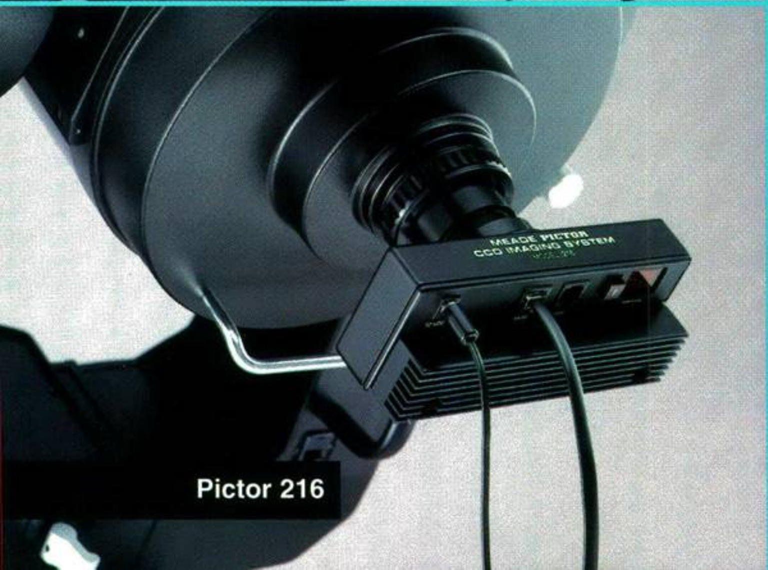
Pictor 1616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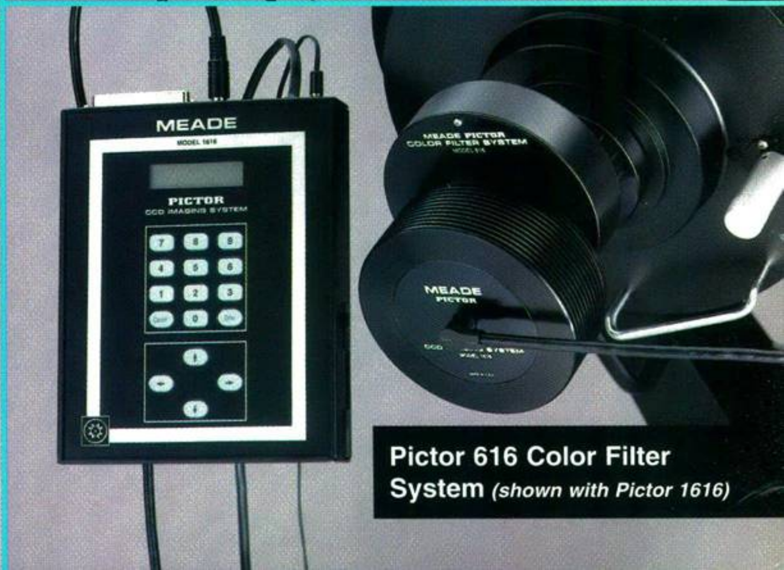
Pictor 216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Pictor 616 Color Filter System *(shown with Pictor 1616)*

Pictor™ Series CCD IMAGERS

For the beginner, or for the most advanced observer, the *real* CCD revolution is here!

Imagine—*with your telescope*—capturing an image of Jupiter that appears to have been taken with a 36" observatory instrument!

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Meade Pictor Series CCD Imagers bring the CCD revolution even to the beginner: all models, including the least-expensive unit, are simple to use, without a multitude of complex adjustments and settings. **And yet, because of state-of-the-art Meade electronic and software design, this simplicity is accomplished simultaneously with the most advanced CCD image resolution and performance in the history of amateur astronomy.**

From the Pictor 201 Autoguider at $395, to the Pictor 1616 Professional CCD Imaging System at $6995, and with three models in between, there's a Meade CCD system to fit your budget and your imaging requirements. Each model is the finest obtainable, by far, in its price class.

Pictor 201 Autoguider: The first ultraprecise, moderately-priced CCD autoguider, the Pictor 201 yields flawless, fully automatic photographic guiding on any telescope equipped with a dual-axis drive corrector; optional connectors enable easy interfacing between your drive corrector and the 201 Autoguider. On Meade LX200 and CDS-driven APO models, or on other telescopes equipped with a CCD/autoguider jack, the self-contained 201 plugs directly into the telescope's power panel; no host PC or separate control box is required. Used with an off-axis guider and 35mm camera body, the Pictor 201 locks on to a guide star and automatically makes all required dual-axis corrections for perfectly guided astrophotographs. Use it *once*, and you'll never manually guide again! **$395*** + $10 packing and shipping in the 48 states.

Pictor 208 CCD Autoguider/Imager: Incorporating the Texas Instruments TC-255 CCD microchip, the Pictor 208's 3.3mm x 2.4mm active area is the largest available in any CCD unit under $1500. Ideal for the beginning CCD user, the thermoelectrically cooled 208 includes an 8-bit A/D register permitting 256 shades of image brightness. The Pictor 208 requires no external control box: all microelectronics and control buttons are housed on or within the small 5.5" x 2" x 1.7" main unit. Operation is through any Windows™ or Mac™-based PC. Simple to use, quick to set up, *the Pictor 208 is perfect for the demanding first-time CCD user on a more limited budget.* When used with a Meade LX200 and electric focuser, the 208 permits autofocusing and auto-mosaic features. Autoguiding circuitry, software, and capabilities are identical to the Model 201, above. **$795** + $15 P & S.

Pictor 216 CCD Autoguider/Imager: Identical in operation and size to the Model 208, and designed around the same Texas Instruments TC-255 CCD chip, the Pictor 216 includes a major advantage: a 16-bit A/D converter permitting 65,536 brightness levels. The result is a level of image quality only obtainable on competing units that sell for almost twice the 216's price. Combining high-resolution imaging with low dark current, the Pictor 216 satisfies the long-term CCD imaging requirements of the majority of serious amateurs. **$1195** + $15 P & S.

SPECIFICATIONS: MEADE PICTOR SERIES AUTOGUIDER/IMAGERS

	Pictor 201	Pictor 208	Pictor 216	Pictor 416	Pictor 1616
CCD Chip	Tex. Instr. TC-255	TC-255	TC-255	Kodak KAF-0400	Kodak KAF-1600
Dimensions	3.30 x 2.40mm	3.30 x 2.40mm	3.30 x 2.40mm	6.90 x 4.60mm	13.80 x 9.20mm
Pixels	336 x 242	336 x 242	336 x 242	768 x 512	1536 x 1024
Pixel Size	10.0 µm square	10.0 µm square	10.0 µm square	9.0 µm square	9.0 µm square
In 8" f/10 telescope:					
Pixel Size	1.0 arc secs	1.0 arc secs.	1.0 arc secs.	0.9 arc secs.	0.9 arc secs.
Field of View	5.6' x 4.1'	5.6' x 4.1'	5.6' x 4.1'	11.7' x 7.8'	23.3' x 15.6'
Full Well Capacity (e-)	70,000	70,000	70,000	85,000	85,000
Dark Current	87e-/5 secs. @20°C	< 8e-/5 secs. @ -5°C	< 8e-/5 secs. @ -5°C	< 1e-/5 secs. @ -20°C	< 1e-/5 secs. @ -20°C
A/D Conversion	8 bit	8 bit	16 bit	16 bit	16 bit
Brightness Levels	—	256	65,536	65,536	65,536
Thermoelectric Cooling	none	-25°C	-25°C	-40°C, 2-stage	- 40°C , 2-stage
Shutter	—	electronic	electronic	electro-mechanical	electro-mechanical
SCSI Interface	—	no	no	yes	yes
With LX200 Telescope:					
Auto-focus Capability	—	yes	yes	yes	yes
Auto-mosaic Capability	—	yes	yes	yes	yes
Accepts #616 Color Filter System	—	no	yes	yes	yes
Dimensions: Head	5.5" x 2" x 1"	5.5" x 2" x 1.7"	5.5" x 2" x 1.7"	5" dia. x 2.2"	5" dia. x 2.2"
Controller	—	—	—	9" x 7" x 1.2"	9" x 7" x 1.2"
Price (plus packing & shipping)	$395	$795	$1195	$2495	$6995

Pictor 416 CCD Autoguider/Imager: Armed with the powerful Kodak KAF-0400 CCD microchip, the Pictor 416 is the most advanced high-resolution CCD system available under $5000. The 416 includes more than *four times* the pixel quantity, more than *twice* the pixel density, and about *one-tenth* the dark current of competing units. And, with its standard-equipment SCSI interface, *the 416 can full-frame download to its host computer in one second!* The Pictor 416 is a powerful CCD system on any telescope; attached to a Meade LX200, its capabilities are truly awesome: the auto-mosaic feature, for example, permits imaging of an arbitrarily large sky area, creating an image-montage of adjacent sky regions *automatically* on user command. **$2495** + $25 P & S.

Pictor 1616 CCD Autoguider/Imager: For professional-level applications, the Meade Pictor 1616 utilizes the Kodak KAF-1600 CCD microchip, one of the largest (13.80 x 9.20mm) such chips currently in commercial production. Identical in pixel density and dark current to the Pictor 416, but with 4 times the chip area, the 1616 permits imaging of very large sky areas and is the finest CCD imaging system available at under-$10,000. **$6995** + $40 P & S.

#616 Color Filter System: Complementing Pictor Models 216, 416, and 1616, the Model 616 Color Filter System enables superb tri-color imaging, *fully-automatically,* without the tedious trial-and-error approach of competing units. Choose the object-type or planet to be imaged, and the Pictor's software does the rest, rotating each color filter into position and correctly timing each exposure for the optimal tri-color result. Alternately, color imaging may be performed in the manual-mode, according to user command. Special Poisson-curve interference filters, unique to the Meade filter system, achieve levels of color fidelity heretofore unavailable. **$695** + $10 P & S.

- *All prices shown are suggested U.S.A. mail-order prices, not including any applicable sales taxes.
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Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE COMPANY, Burbank, CA.
Orders: 800-843-4780; Info.: 818-505-8424.

CITY CAMERA, Dearborn, MI.
Orders: 800-359-5085; Info.: 313-846-3922.

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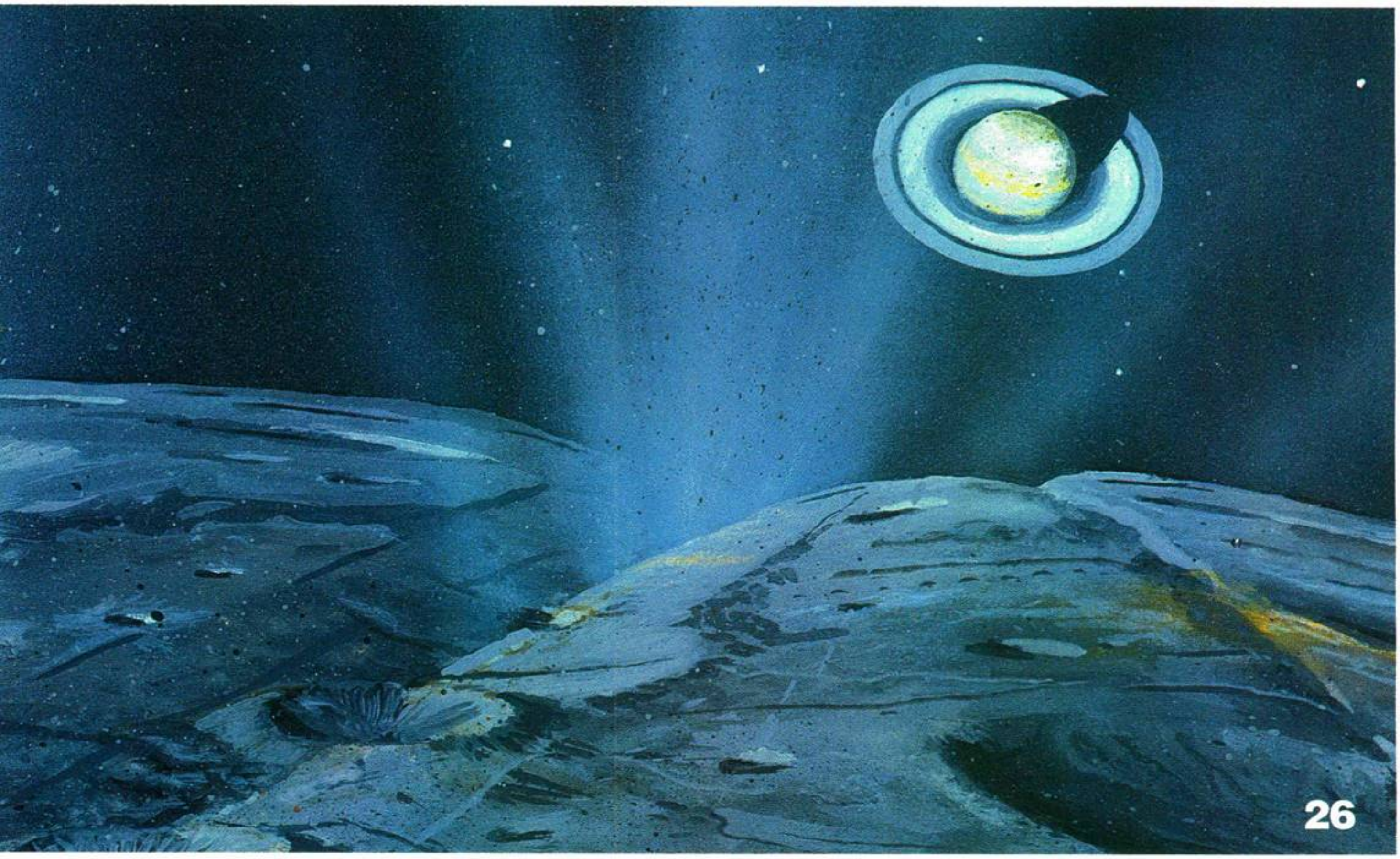

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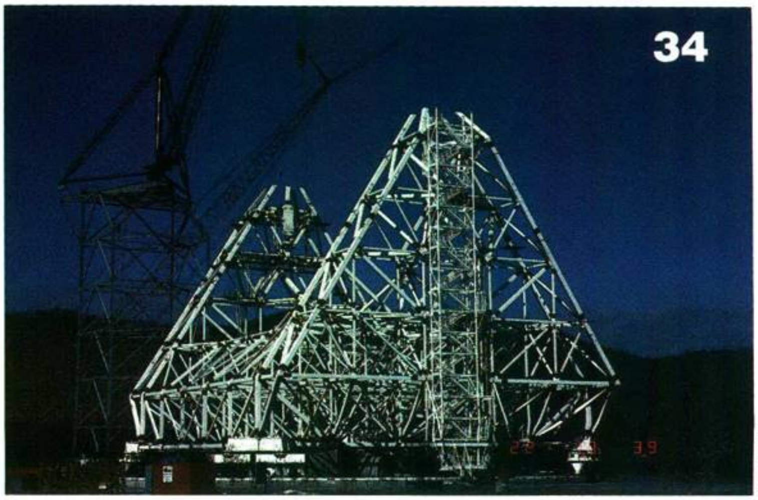

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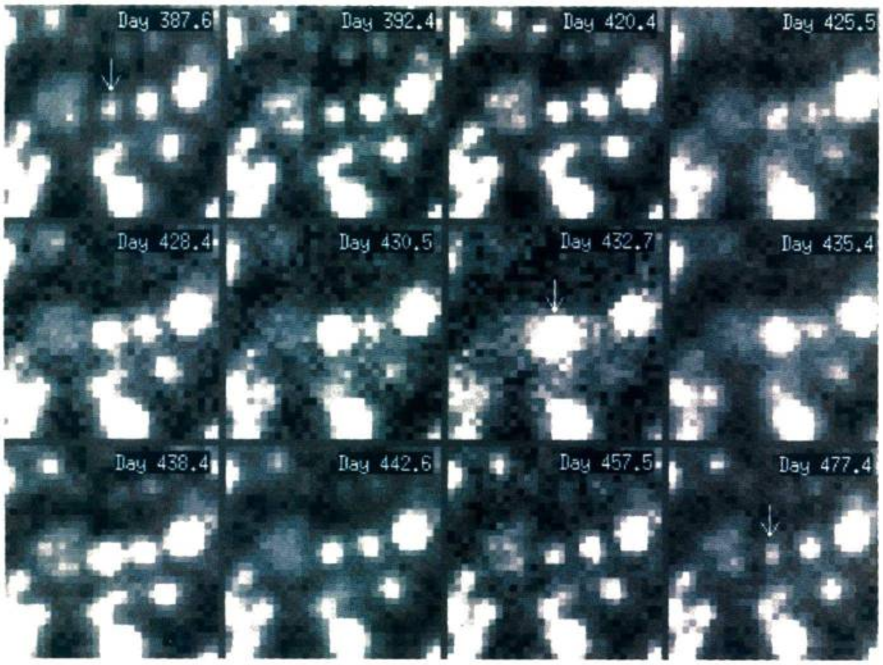

Charles Alcock, et al./Lawrence Livermore National Laboratory

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COVER

THE CRASH IS HERE! July 16 marks the beginning of a week unprecedented in the annals of astronomy: the first ever view of a comet smashing into a planet. For the latest on Comet Shoemaker-Levy 9's impending demise, see page 72. Illustration by Don Davis.

BEHIND THE SCENES

Watching Astronomy Change

"Relax," replied Alan Stern. "Soon it'll be like the main asteroid belt. We have to live with the fact there's going to be lots more discoveries."

I had e-mailed Alan in a panic as soon as word came out that David Jewitt and Jane Luu had found two new distant solar system objects (see last month's AstroNews). Alan's story about the Kuiper disk (on page 26 of this issue) was well along in preparation. I foresaw a pile of frantic last-moment changes to reflect the new findings. *(And what if somebody found even more new objects while the magazine was in press. . . ?!)*

But editors are habitual worry warts. As it happened, the new discoveries were easy to slip into the story. The bigger picture is that if it's sometimes a hassle to cover a story that evolves as you fly down toward deadline, nothing beats it for excitement.

"But you know," Alan continued, "the big problem isn't discovery. It's follow-up. Discovering these things is only the first part of the deal. To understand them, we've got to stay on top of them. Keep track of them to nail down their orbits and their physical properties. Analyze what happens over the long term. That's what it'll take to learn about this new part of the solar system we're seeing."

If the Sun has a new-found retinue of dim, distant Chirons, or "centaurs," that astronomers are just now beginning to explore, something parallel is going on in cosmology. Wallace Tucker's story about dark matter and MACHOs — massive dim objects in the Milky Way's halo — makes an eerie counterpart (see page 40). Only these objects aren't a few light-hours out from Earth; they're more like 60,000 light-years away. And how astronomers discovered them sounds almost like science fiction.

Imagine yourself trying to spot meteors by lying back and looking at the whole sky all at once. (Anyone who has tried it knows it's tougher than it sounds.) Now imagine watching a million stars all at once and trying to spot the one that changes brightness, in precisely the right way, over many weeks or months. Yet that's in essence what the astronomers Tucker writes about did to find their MACHO. Were they lucky? Or did they know just where to look? Actually, it was a little of both. Theory steered them right, and technology made it possible.

Their discovery promises to be as revolutionary in cosmology as the new findings closer to home will be for planet studies. By themselves MACHOs probably won't be enough to settle the dark matter problem. But they're a start — and in themselves they pose highly interesting possibilities for study.

Astronomy has always been driven by its bias for bright objects. Yet year by year, new techniques push detector limits to ever fainter magnitudes. And right in step, it seems, the universe unfolds a little further in complexity. I doubt anyone can say where this is going to end, but the process is sure fascinating to observe and report on.

Sincerely,

Robert Burnham

Robert Burnham
Editor

LETTERS

How Do I Hate Thee? Let Me Count the Ways

Jim Marsh's article "Teaching Them to Hate Astronomy" (May 1994) deals with missed opportunities to attract students to astronomy. It brings out a key problem in astronomy education: Too many instructors of astronomy courses for non-science students fail to appreciate the motivations that draw large numbers of them into such courses.

Too many professional astronomers teaching in the field confine their interest to astronomical applications of physical principles, the realm beyond our Galaxy, and other subjects emphasized in graduate school. Where are the teachers who stay cognizant about the Moon, planets, and visual aspects of the sky? — *Arthur Upgren, Van Vleck Observatory, Wesleyan University, Middletown, Connecticut*

While a few of Mr. Marsh's statements make sense, he has not taken into account a number of other considerations. Many professors do tailor their courses to meet the needs of students. For many non-science majors, an astronomy course is the only science they'll experience in college. So it's important to expose students to certain concepts.

Learning about experimentation and the role of mathematics in reasoning and in developing ideas is central to clear thinking. In learning about astronomy students are also learning about the good reasons for science.

I doubt that most students have learned to hate astronomy. In my admittedly limited experience, a few are disappointed — often those who are too advanced for an introductory course. Many enjoyed the course but had to work a little harder than they would have liked to. And some became true enthusiasts. I think that says that astronomy courses, most of them at least, are working pretty well. — *Christine Brunello, Amarillo, Texas*

(continued on page 13)

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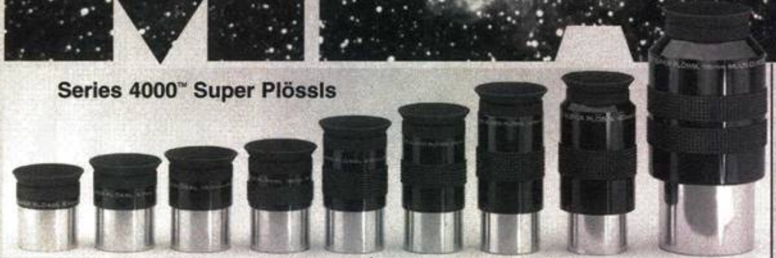
Series 4000™ Super Plössls



Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types for 1994, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm	each:	**$87.95** (3.29)
32mm (52°); **40mm** (44°)	each:	**109.95** (3.79)
56mm (52°; 2")		**229.95** (5.48)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5° at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.

$129.95 (3.60)

Series 4000™ Super Wide Angle

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The ultimate eyepieces; extreme image sharpness over an amazing 84° field.

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each	**$14.95** (2.29)
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Set #1–4 filters: #12, #23A, #58, #80A	**54.95** (2.98)
Set #2–4 filters: #11, #25A, #47, #82A	**54.95** (2.98)
Set #3–4 filters: #8, #21, #38A, #56	**54.95** (2.98)
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Sets #1, #2, & #3–12 filters	**144.95** (3.79)

#911B
#910B
#908B
#911N
#910N
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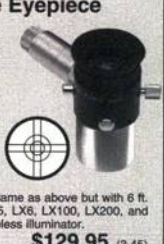
#908B–Threads into 1.25" eyepieces, 26mm dia.	**79.95** (2.98)
#910B–Threads into 2" eyepieces, 44mm dia.	**119.95** (3.29)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (3.29)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (2.98)
#910N–Threads into 2" eyepieces, 44mm dia.	**129.95** (3.29)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (3.29)

World's Most Advanced Illuminated Reticle Eyepiece



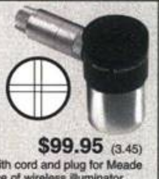
Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. **Internal batteries included.** Multi-coated optics. Bullseye reticle. 1.25"

$149.95 (3.45)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (3.45)

MA 12mm Illuminated Reticle Eyepiece



Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Wireless red LED illuminator and variable brightness control. **Batteries included.**

$99.95 (3.45)

MA 12mm—Same as above but with cord and plug for Meade telescopes with power panels, in place of wireless illuminator.

$79.95 (3.45)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **$99.95** (3.79)

Camera Adapters (1.25" & .965")

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

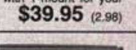
.965": $27.95 (2.98) **1.25": $29.95** (2.98)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (2.98)

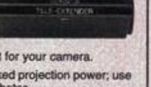
Tele-Extenders



For Eyepiece-Projection photography with any Meade or Celestron SCT. Threads on to any eyepiece-holder. Use with T-mount for your camera.

Basic Tele-Extender: *(above)* Fixed projection power; use with eyepiece for lunar and planetary photos.

$29.95 (2.98)



Variable Tele-Extender: Sliding cell, with lock, permits wide range of projection magnifications with the same eyepiece.

$39.95 (2.98)

T-Adapters for SCT's

For Prime Focus photography with any Meade or Celestron SCT. Use with T-Mount for your 35mm camera.

$26.95 (2.98)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (3.45)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25"

$59.95 (3.45)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated.

$47.95 (3.45)

Modified Achromatic Eyepieces

An improvement on the traditional Kellner design, these 3-element Modified Achromatic eyepieces give sharp, faithful, well-corrected images of the moon, planets, and deep-space at an economical price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (2.98)

HOW TO ORDER

■ Prices shown are suggested USA mail-order retail prices and do not include any applicable sales taxes.

■ Suggested shipping and handling charges to the 48 states by UPS or US Mail shown in ( ) next to each price.

■ Meade accessories may be ordered from any Meade Advanced Products Dealer. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE CO., Burbank, CA.
Orders: 800-843-4780; Info.: 818-505-8424.

CITY CAMERA, Dearborn, MI.
Orders: 800-359-5085; Info.: 313-846-3922.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 510-447-9570.

SHUTAN CAMERA & VIDEO, Chicago, IL.
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Orders & Information: 416-783-4140.

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MEADE
12" LX200
10" LX200
(shown with optional Superwedge)
8" LX200
MEADE LX200 EMC

Supplied complete per catalog specifications**:

8" LX200 Schmidt-Cassegrain	**$2295.**
10" LX200 Schmidt-Cassegrain	**$2895.**
12" LX200 Schmidt-Cassegrain	**$3995.**

Packing & shipping in 48 states: 8"—$105; 10"—$145; 12"—$215.

- **All prices shown are suggested USA mail-order retail prices, exclusive of sales taxes or credit card charges, if applicable.
- For dealer or catalog information see the **Meade Starfinder Reflecting Telescope** ad in this issue.

If you're thinking of buying a computer-controlled Schmidt-Cassegrain, consider why Meade® LX200's are the largest-selling serious telescopes in the world:

1. More than *three times* the pointing accuracy—Other computer-controlled Schmidt-Cassegrains vaguely promise a "***potential*** pointing accuracy of 0.09°." Meade LX200's in the altazimuth mode include precise corrections for atmospheric refraction and precession, and are **guaranteed to locate and place objects to within a pointing accuracy of 0.03°**, an accuracy that places objects **virtually dead-center in the field**. For CCD astronomy, with its inherent demands on telescope pointing accuracy, for locating and observing objects near the threshold of visibility, or simply to avoid constant re-centering of objects, a Meade LX200 is the essential tool of the advanced amateur.

2. Legendary Meade Super Multi-Coated (EMC) optics—The finest Schmidt-Cassegrain optics available, **multi-coated, as standard equipment, on all optical surfaces for maximum light transmission and image contrast.** *Competing SCT's do not offer multi-coatings even as an option.*

3. High-torque dual-axis drive systems—Powerful **18-volt** DC drives that operate **from any 115v.AC outlet**, using the small, standard-equipment AC Adapter **or from any 12v. automobile cigarette lighter plug**, using the exclusive Meade 12v./18v. Electronic DC Adapter (an optional accessory that weighs only 4 ounces). ***LX200 drives produce high torques impossible to achieve and sustain with competing penlight-battery powered telescopes.*** The LX200 easily handles additional payloads of a CCD imager, piggybacked guide telescope, or other auxiliary equipment; even with such additional weight, the telescope moves effortlessly across the sky, either automatically or by observer pushbutton control, at speeds from the sidereal rate to 8°/sec.

4. Heavy-duty fork mounts—By a wide margin the largest, most rigid in the industry, complemented by giant 4"-diameter polar ball bearings and by DC-servo-motor-driven worm gears on both telescope axes.

5. *Nine-speed* drives on both axes—Including photo-guiding (at **2x** sidereal rate); image centering and microslewing in the main telescope (at **32x** sidereal rate); image centering in the viewfinder (at **2°/sec.**); or fast-slew of the main telescope at any rate between **3°/sec** and **8°/sec.**, in **1°/sec.** increments.

6. *Thirty-six* built-in tracking rates—From quartz-controlled sidereal-rate tracking to incrementally variable solar, lunar, and planetary rates.

7. Permanently programmable Smart Drive™—Reduces periodic drive errors to 5 arc secs. or less, an observatory standard. Program ***once*** and store in memory indefinitely, even when the telescope is turned OFF.

8. Upgradable object-database library—Object databases on competing computer-controlled SCT's are *non-upgradable and fixed in size.* The LX200 allows for much larger object-databases. **And, for a limited period, you can obtain the Meade 64,350-object database FREE of charge!** *(See box at right.)*

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GO TO
N
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SLEW 7
RET 8
M 9
FIND 4
FOCUS 5
STAR 6
CNTR 1
MAP 2
CNGC 3
GUIDE 0
PREV
NEXT

The modern design of the LX200 hand controller permits more than a dozen user functions, from automatic actuation and centering of any object in the 64,350-object database to brightness control of an illuminated reticle eyepiece.

9. Advanced Hand Control Design and Software—Competing telescopes do not even include a numerical keypad! To enter an object from the database, for example, you must scroll through each digit, ***typically using 20 to 30 keystrokes***. By comparison, the random-access software controlling the LX200's numerical keypad requires a **maximum** of 5 to 7 keystrokes. LX200 user-definable "sky tours" by object-type, brightness, and position may include every deep-space object in the 64,350-object database, if desired, or any user-defined subset thereof.

10. Ultra-reliable electronic systems—*Thousands* of Meade LX200's have been sold worldwide. State-of-the-art designs and production systems, combined with exhaustive laboratory and field testing, make these **the most trouble-free serious telescopes ever manufactured.**

11. Meade Version 3.20 software—The very latest in telescope operating systems. Permits quick ***(less than 10 seconds!)*** 2-star alignment of the LX200 in altazimuth mode, without requiring latitude or longitude input, without even leveling the tripod. Just use 2 easy-to-find reference stars and the telescope tracks and actuates GO TO with extreme precision.

FREE!

Through August 31, 1994, receive the Meade 64,350-object library at *no charge* when you order any 8", 10", or 12" LX200!

Buy a Meade 8", 10", or 12" LX200 Schmidt-Cassegrain before August 31, and we'll include the Meade 64,350-object database at no additional charge! Imagine having 64,350 celestial objects at the tip of your finger: *64,350 objects that you can actuate and center in the telescopic field just by entering and pressing GO TO on the hand controller.* **More than 6 times the size of object libraries included with competing telescopes**, the Meade 64,350-object library includes an incredible array of phenomena—virtually a lifetime of deep-space study, even for the advanced observer:

12,921	galaxies from the Uppsala General Catalog; the complete UGC catalog.
7,840	objects from the New General Catalog; the complete NGC catalog.
5,386	IC (Index Catalog) objects; the complete listing of IC objects.
21,815	variable stars; the complete listing from the General Catalog of Variable Stars.
15,928	stars from the Smithsonian Astrophysical Observatory (SAO) catalog of stars brighter than 7th magnitude.
351	alignment stars for the LX200 telescope.
110	Messier objects; the complete listing.
8	major planets from Mercury to Pluto.
64,359	**objects, total**

This special offer applies to telescopes ordered from your authorized Meade Advanced Products dealer between May 20 and August 31, 1994.

SPECIFICATIONS: 8", 10", and 12" LX200's—Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 SC optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function power panel display on the drive base; manual slow-motion controls on both axes; keypad handheld controller with digital readout display, permanently programmable Smart Drive™, 9-speed drive controls on both axes (7-speed on 12"), and GO TO controller; 64,350-object onboard celestial software library**; 25 ft. power cord and adapter for telescope operation from 115v.AC (DC capability for operation from auto cigarette lighter plug available optionally); 8 x 50mm viewfinder with crosshairs; 1.25" diagonal prism (8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (8", 10") or giant field tripod (12"); foam-fitted carrying case; complete operating instructions.
**Included during period of special offer, only.

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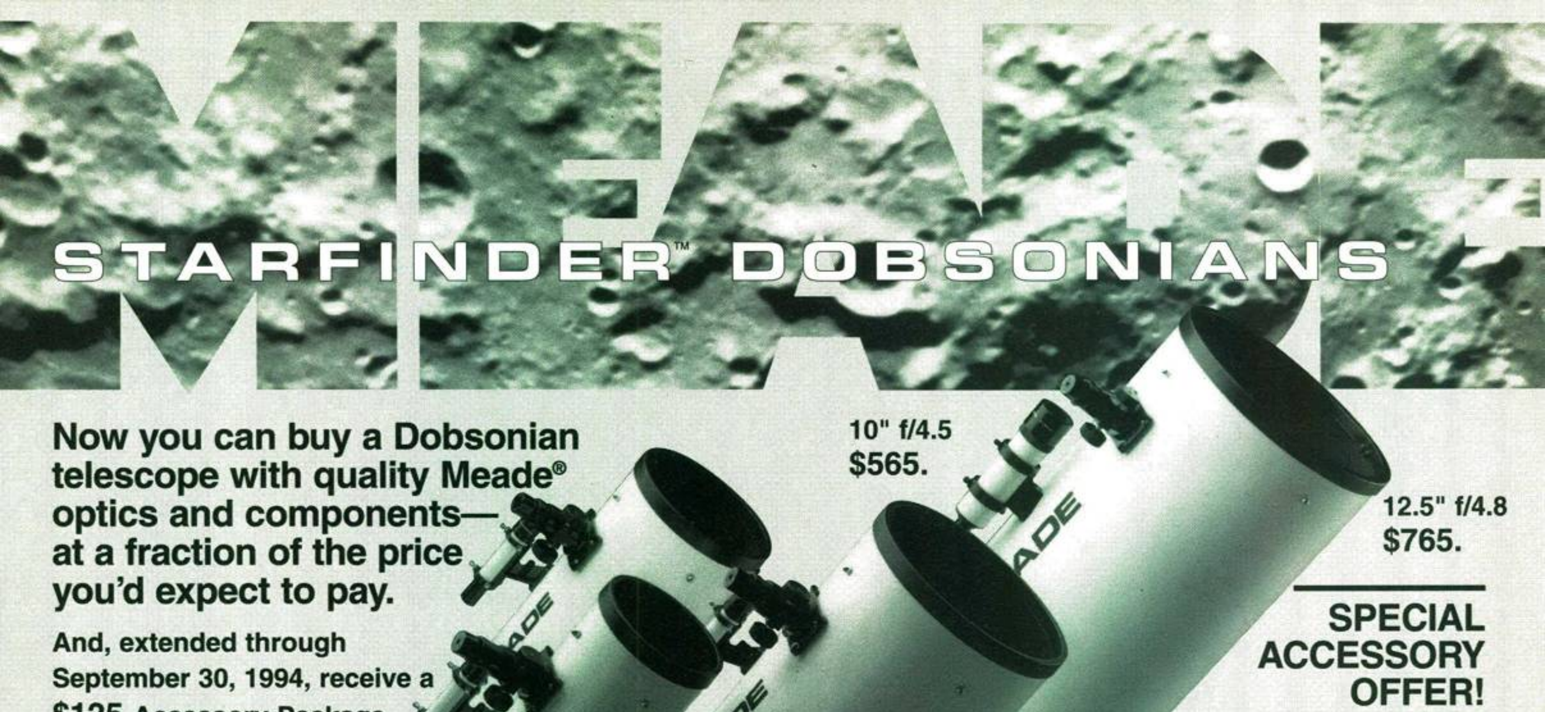

STARFINDER™ DOBSONIANS

Now you can buy a Dobsonian telescope with quality Meade® optics and components—at a fraction of the price you'd expect to pay.

And, extended through September 30, 1994, receive a $125 Accessory Package for only $29.95!

10" f/4.5
$565.

12.5" f/4.8
$765.

8" f/6
$395.

6" f/8
$295.

Shown with optional #637 6 x 30mm or #545 8 x 50mm Viewfinders

SPECIAL ACCESSORY OFFER!

Through September 30, 1994, at the time you order any Starfinder 6", 8" 10", 12.5", or 16" Dobsonian Telescope, you can buy **two additional Meade multi-coated Modified Achromatic MA9mm and 12mm eyepieces *and* the Meade #637 6 x 30mm coated achromatic viewfinder for a *total* of only $29.95! Purchased separately, the 2 additional eyepieces and viewfinder sell for $125.85!** *(Shown in photo: MA9mm, MA12mm, and standard-equipment MA25mm eyepieces, with #637 6 x 30mm viewfinder.)*

Starfinder Dobsonian 16

16" f/4.5
$1195.

See the Meade General Catalog for details.

Includes giant #682 focuser; shown with optional 8 x 50mm viewfinder.

Compare Meade Starfinders *feature-for-feature* with other similarly priced Dobsonians!

- **Primary and Secondary Mirrors of Low-Expansion Pyrex® glass!** Unlike the plate-glass optics of other Dobsonians that can become thermally unstable (especially in larger apertures), Meade Dobsonians include the *exact same* professional-quality Grade-A, fine-annealed Pyrex® optical systems used on Meade Starfinder Equatorial Reflectors. Optics that meet the theoretical limits of resolution for their apertures.
- **Precision Rack-and-Pinion Focuser!** An industry-standard full-size rack-and-pinion system with 2.6" of focus travel.
- **Fully-Adjustable 4-vane Secondary Mirror Systems!** *Rigid 4-vane systems* that permit precision alignment of the secondary mirror to the primary mirror.
- **Rigid, Durable, Beautiful Dobsonian Mountings!** Mountings that provide extremely smooth motions of the telescope in both altitude and azimuth. Both telescope axes ride on zero-backlash Teflon/Nylon bearings, facilitating the location and tracking of celestial objects anywhere in the sky. Each mount is manufactured of cabinet-quality materials and designed for a lifetime of use. Handles are provided for easy portability.
- **Optical Tubes:** Starfinder Dobsonians include the same strong, spiral-wound optical tubes used on Starfinder Equatorials *(facing page)*. All telescopes include a multi-coated MA25mm eyepiece as standard equipment. Each tube is factory pre-drilled for the optional 6 x 30mm or 8 x 50mm viewfinder.
- **Performance!** A Meade Starfinder Dobsonian or Equatorial Telescope opens up the skies to an extremely wide range of serious visual observing: all 110 Messier objects, thousands of NGC objects–nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets in stunning, high-resolution detail. Starfinder Dobsonians are telescopes for visual observing; motor-driven Starfinder Equatorials may be used, in addition, for lunar and planetary photography and even for limited deep-space astrophotography.
- **Packing and UPS Shipping Charges:** to any address in the 48 states: 6"–$39; 8"–$49; *10"–$69; 12.5"–$79. 16"–$45 packing*, shipped truck freight collect.
- **To Order:** Contact one of the authorized mail-order dealers on the facing page.

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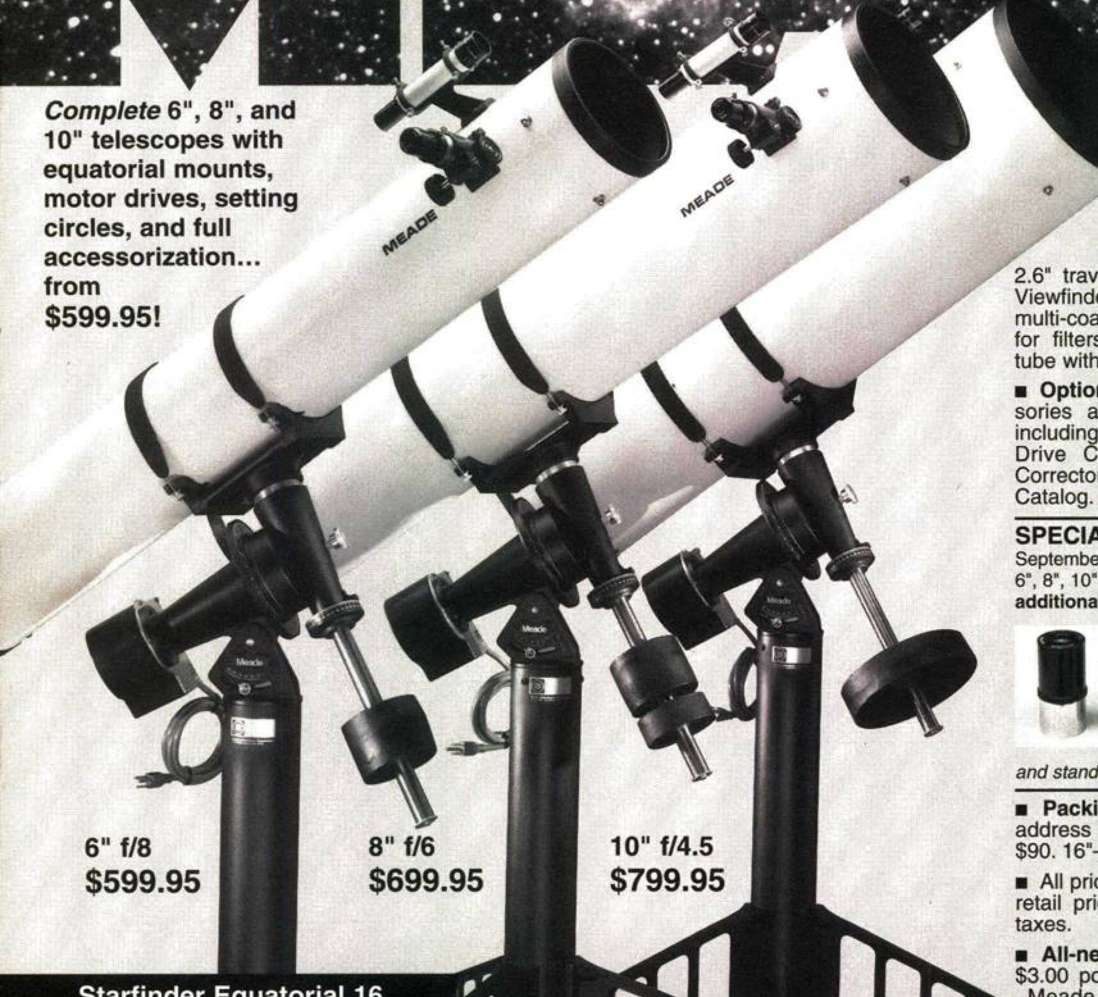
STARFINDER™ EQUATORIALS



Complete **6", 8", and 10" telescopes with equatorial mounts, motor drives, setting circles, and full accessorization... from $599.95!**

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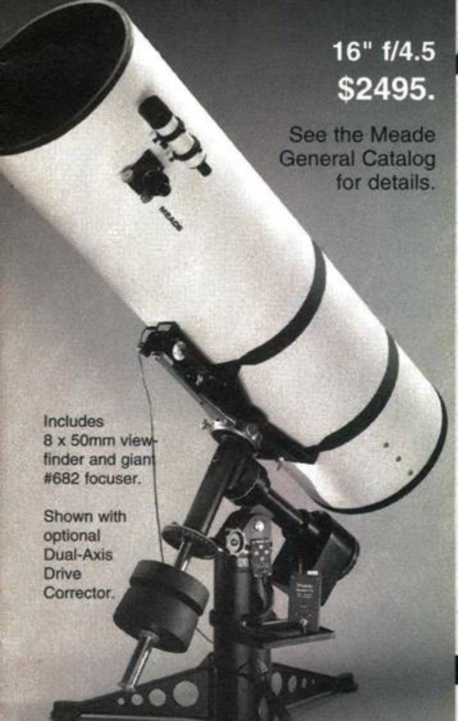
10" f/4.5
$799.95

Starfinder Equatorial 16



16" f/4.5
$2495.

See the Meade General Catalog for details.

Includes 8 x 50mm viewfinder and giant #682 focuser.

Shown with optional Dual-Axis Drive Corrector.

Standard equipment on 6", 8", and 10" models includes:

- **Superb Optical System:** Includes hand-figured parabolic primary mirror that meets the theoretical limit of resolution for its aperture, with matching elliptical flat secondary mirror. Both mirrors multi-coated and made of low-expansion, Grade A, fine-annealed Pyrex® glass.
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- **Standard Accessories and Components:** Precision Rack-and-Pinion Focuser (1.25") with full 2.6" travel; coated achromatic #637 6 x 30mm Viewfinder with crosshair eyepiece and 7° field; multi-coated MA25mm (1.25") eyepiece, threaded for filters; strong, durable, spiral-wound optical tube with attractive white finish.
- **Optional Accessories:** See the Meade accessories ad in this issue. Additional systems, including #55 Manual Declination Control, #43 Drive Corrector, and #47M Dual-Axis Drive Corrector, are described in the Meade General Catalog.

SPECIAL ACCESSORY OFFER! Through September 30, 1994, at the time you order any Starfinder 6", 8", 10", or 16" Equatorial Telescope, you can buy **two additional Meade multi-coated Modified Achromatic MA9mm and 12mm eyepieces for a *total* of only $19.95! Purchased separately, the two additional eyepieces sell for $75.90.** *(Shown in photo: MA9mm, MA12mm, and standard-equipment MA25mm eyepieces.)*

- **Packing and UPS Shipping Charges:** to any address in the 48 states: 6"–$65; 8"–$75; 10"–$90. 16"–$55 packing, shipped truck freight collect.
- All prices shown are suggested USA mail-order retail prices, not including any applicable sales taxes.
- **All-new 1994-95 Meade General Catalog**–$3.00 postpaid–is available from any authorized Meade dealer or directly from Meade Instruments.
- For further information call Meade Instruments at 714-756-2291 or contact one of these authorized mail-order dealers:

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CALIFORNIA TELESCOPE COMPANY, Burbank, CA.
Orders: 800-843-4780; Info.: 818-505-8424.

CITY CAMERA, Dearborn, MI.
Orders: 800-359-5085; Info.: 313-846-3922.

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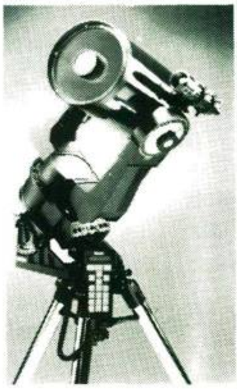

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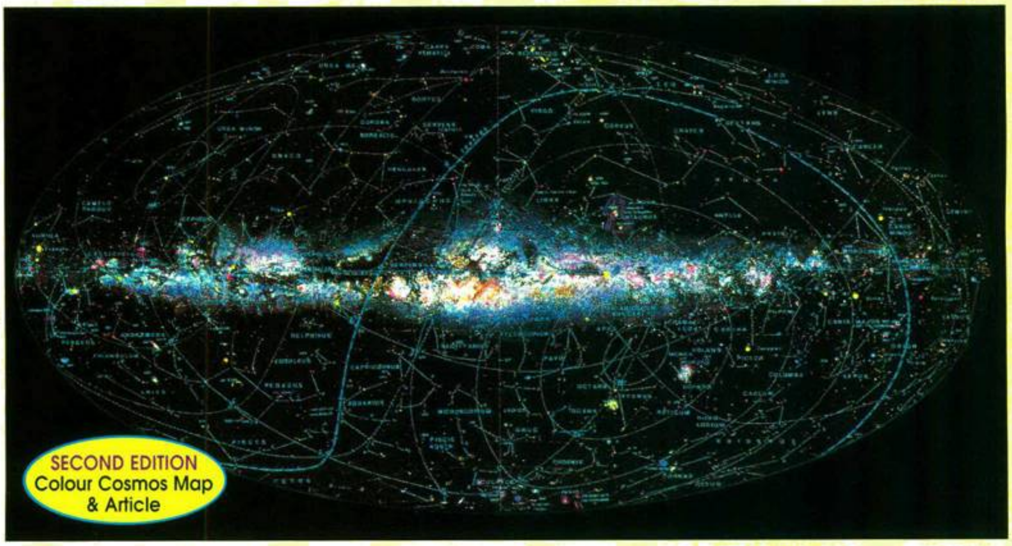

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Pluto in a 6-inch Scope

In your "Sky Almanac" section Deborah Byrd and Jeff Kanipe reported that at least an 8-inch telescope is necessary to spot Pluto (May 1994). In the same issue, John Shibley commented in "Take the Pluto Challenge" that an 8-inch scope is the smallest one can use to spot the distant planet.

At this year's Winter Star Party, however, a friend and I observed Pluto in 20-inch and 25-inch reflectors and, once we knew its exact location, spotted it in a 5.7-inch scope. Although it was very faint and blinked in and out of visibility, we definitely observed it. Under really dark skies, I think it might be possible to see Pluto in a 5-inch scope. — *Richard Whalen, Clearwater, Florida*

— The minimum apertures given for various objects in our articles are of course general guidelines. We have in mind a reasonably good sky, darker and steadier than average. Of course there are exceptions to generalities and under excellent conditions you can frequently see objects in smaller telescopes than those we cite, especially if you already know where to find the object.

The British Fight for Dark Skies

I was interested and saddened to read Hans Gunter Gnodtke's letter concerning the loss of protection against light pollution in Germany (April 1994). The reaction of the Bundestag is all the more amazing in an environmentally conscious country where there are controls on smoke (burning leaves), noise (lawn mowing on Sundays), and packaging (returning empty containers to retailers).

The British Astronomical Association's Campaign for Dark Skies is having some success in the United Kingdom. I have been involved with the endeavor to reduce the glare from security lighting at a defense establishment situated on the horizon of my observing site. As a consequence of our efforts, the Ministry of Defense has agreed to reconsider their lighting policies in conjunction with consultants they have hired.

It certainly is wrong to say that "stray light is an inevitable consequence of civilization." Remedies do exist. — *Alex E. Davis, Stroud, Gloucestershire, England*

Telescope Advice Appreciated

Thanks to Alan Dyer for his article on the Orion Deep Space Explorer 6-inch and 8-inch scopes (December 1993). The article helped me, an 11-year-old boy, to purchase a great telescope. My 6-inch Deep Space Explorer arrived yesterday, and my Dad and I used it tonight to see Venus and the Orion Nebula. I will use it to observe many other objects in the future. — *Matt Zeltwanger, Hancock, Minnesota*

Eclipse Meteor Memories

Thanks for the great coverage of the November 1993 lunar eclipse (April 1994). In November, my family was vacationing in the Arkansas mountains at a state park. The sky was clear and crisp. We watched the eclipse begin and develop as it deepened into totality. My brother filmed it with his camcorder.

After returning home we watched the tape and saw a meteor flash across the Moon's face. Did anyone else see this? My gut feeling is that a meteor crossing an eclipsed Moon is a rare occurrence. *— Shannon Minshaw, Dallas, Texas*

An End or a Beginning?

The letter to the editor titled "The End of the Road" by Mark Hladik (May 1994) was a typical missive of woe about the lot of us lowly and humble amateur astronomers. It reflects what I would call, metaphorically, a lack of parallel aim between the writer's finder and his main scope. As an amateur obviously cherishing what the sky's sparkling stars have to offer, he is uncharacteristically letting his bliss and his resources get out of alignment. How long did the writer have to wait to get his Newtonian after first dreaming about it 30 years ago? Some time, I would guess. But hasn't that scope given him lots of pleasure? Advice to Mr. Hladik: Stop complaining — you live in Wyoming! Isn't that "where the skies are not cloudy all day" (and night)? — *Br. Edward Martin, Buffalo, New York*

Hang in there, Mr. Hladik. I can understand your feelings. I too feel intimidated by the surge of gadgetry washing over the astronomical landscape. I have a 2-inch scope. It's the best I can afford, and I observe what I can with it. I can't buy a 10-inch scope, a CCD camera, or a GPS receiver. But Mr. Hladik, you and I can enjoy the beauty of the night sky, something the gadgetry will never be able to equal in stature. — *Bob Meyer, Erie, Pennsylvania*

Correction

The recent article on SETI (AstroNews, May 1994) contained an erroneous address for the SETI Institute. The correct address is 2035 Landings Drive, Mountain View, CA 94043. Scientists at the Institute can also be reached via Internet at phoenix_info@seti-inst.edu. ☐

ASTRONOMY welcomes suggestions and additional information about articles and astronomy in general. Send your letters to ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187, or on Internet, use 72000.2704@CompuServe.com. Letters may be edited for length and clarity.

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(Note: The image that appeared in the April Astronomy advertisement was, through Astronomy's production error, degraded in quality.)

VIEWPOINTS

Imagining vs. CCD Imaging

by Randall Wehler

Another article about charge-coupled devices appeared in my latest astronomy magazine. For the last few months, that's what I have been noticing — more and more articles about CCDs.

No doubt computerized astronomy is here to stay. I own an Apple IIc and recently purchased my first astronomy software to entertain me during my time indoors and to prepare me for my observing time outdoors. Certainly technology like this as well as more advanced forms will push seeing farther and farther toward the edge of the universe. But at what cost? I'm hearing a lot of noise about CCD imaging and it makes me curious. Yet I can't help wondering as I read the articles if too much hype is being made about these devices.

Many amateurs are moving into the realm of computerized astronomy just by owning personal computers. I seriously doubt, though, that many of them own or even have access to CCDs. It can be costly to accommodate this new technology. For example, if I wanted to include CCDs in my observing sessions, I would have to buy a new computer system, a CCD camera, and an image-processing program. I could easily spend a minimum of $2,500 for an entry-level setup or invest thousands if I wanted a more advanced system.

I wonder how many astronomy hobbyists can afford to purchase this kind of new technology and equipment, and if they could, would they be prepared to change their observing practice from an active to a more passive style? I don't think I am.

I'm the sort of observer who likes as-you-see-it results at the telescope. Fiddling around on a computer while a sea of stars passes slowly overhead may be time well spent for some folks. But not for me. Something seems very artificial about staring into a monitor and tapping on a keyboard in order to store images I can enhance to "observe" later. For the time it takes to get a CCD image into final form and, if necessary, with enhanced color, I could have whipped through quite a few nebulae or galaxies with a telescope. All this

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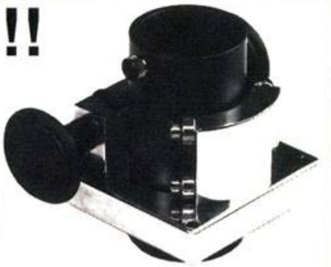

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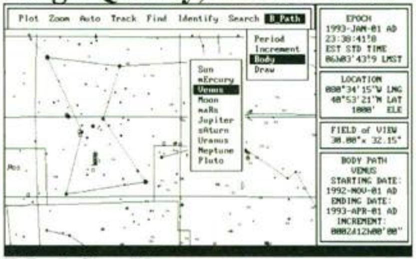

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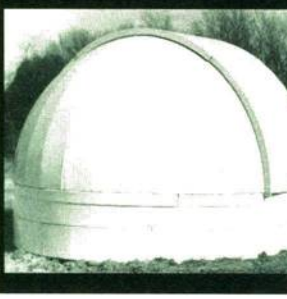

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Call me old-fashioned, but the digitized way makes me feel cheated. CCD images printed in magazines appear . . . well, reconstructed and lackluster compared with the saturated color of film emulsion astrophotographs. And if the CCD images are not bland, then they're on the other end of the spectrum. Sometimes the garish blobs seem a bit too intense. I wonder if I'm really looking at a nebula or a piece of Andy Warhol's Pop Art.

I'd rather see something using my own cortical functions of recall, comparison, recognition, and storage, instead of letting a computer assist me. With my 4-inch equatorial refractor and 11x80 binoculars, I can imagine what is hidden in the corners of the cosmos rather than merely try to image it. Sure, I understand that I cannot see faint objects with as much detail as with a CCD, but I'm seeing them nonetheless.

Nothing compares with the sheer exhilaration I feel after recognizing, with my own eyes, a galaxy or planetary nebula popping into view. I allow myself to be immersed in the mystery of what is beyond my limits. My personal lenses let me sample and glimpse representative inhabitants of the Milky Way, of the universe.

I prefer this kind of challenging hunt, scanning for those elusive lights by using my skills of observation. After all, these same photons now impinging on my retina left ancient celestial sites millions of years ago. In a way, the lenses in my eyes and those in my telescope act as time machines transporting those objects into my imagination. I'd rather process and store telescopic images directly into my mind's eye than onto a computer disk for enhancement at a later time. I know I have a modest memory storage, but my storage capacity is ample enough to meet my needs.

Chemically, I am a carbon-based being. I don't think I'm ready to descend into the silicon valley of higher technology and emerge with a pair of silicon eye glasses. Is it eventually possible for me to be open enough to allow assistance from those pixelated servants of supervision?

Only time will tell.

Do I really want to have CCD capability? Frankly, at this stage of my hobby, no. □

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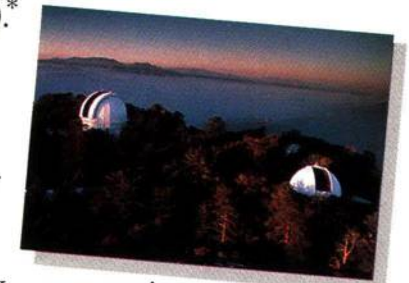

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AstroNews

Milky Way is Devouring Nearby Galaxy

The soft glow of the Milky Way spreads through the constellation Sagittarius, in the direction of the Galaxy's center, which lies beyond and is obscured from view by dust. What no astronomer realized until recently was that this glow hid the presence of a dwarf spheroidal galaxy. Rodrigo Ibata and Gerry Gilmore of the Institute of Astronomy in Cambridge, England, and Mike Irwin of the Royal Greenwich Observatory, also in Cambridge, discovered the newest neighbor on a photograph taken with the UK Schmidt Telescope. Spreading over 10°, the dwarf galaxy lies only 80,000 light-years away from Earth, 50,000 light-years on the other side of the Galaxy's center; by comparison, the Large Magellanic Cloud, previously thought to be the nearest galaxy, lies 170,000 light-years away from Earth.

Normal dwarf spheroidal galaxies have a diameter of about 1,000 light-years, but the gravity of our Galaxy has distorted the Sagittarius dwarf galaxy, stretching it out to about 10,000 light-years across. Astronomers believe the galaxy is moving away from the Milky Way in a 15-billion-year-long orbit. Unfortunately, the galaxy's first encounter with the Milky Way may be its last. The dwarf galaxy is now so spread out that its gravity can't keep the stars together. Some of the stars may eventually become incorporated into the Milky Way.

NRL/Department of Defense

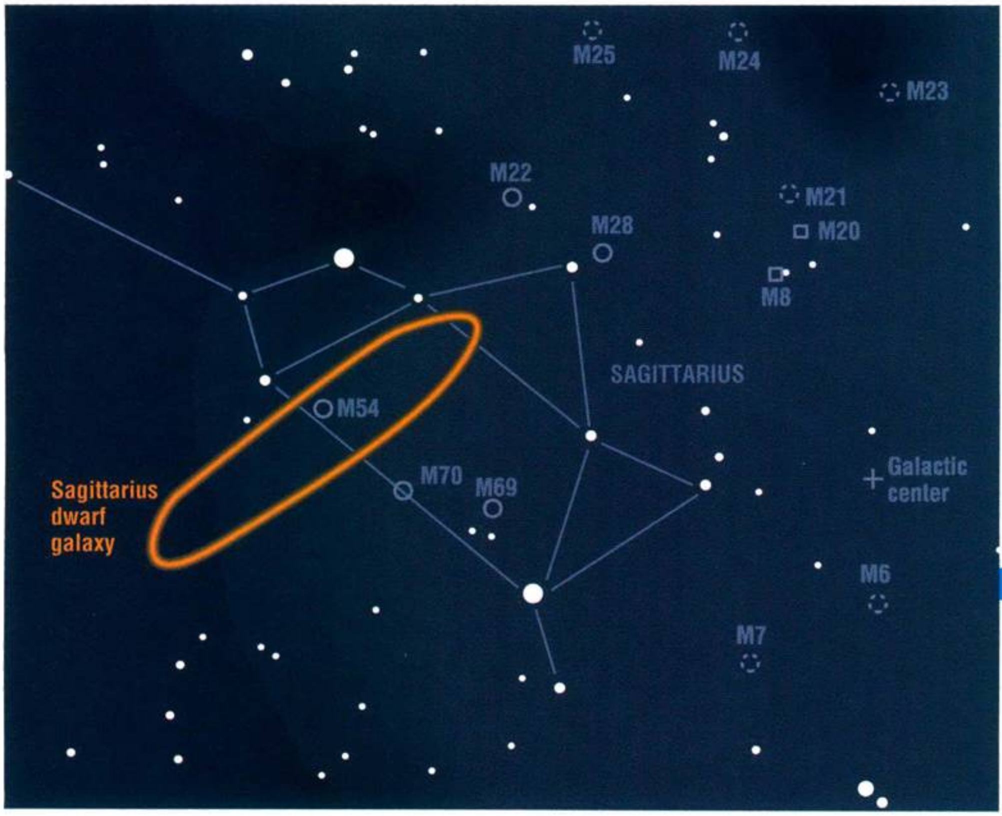
THE ZODIACAL LIGHT FILLS the frame beyond the Moon's limb as a camera on board the Clementine spacecraft captures the sunlight reflected by tiny dust particles scattered among the planets. The bright glare at top is an overexposed image of the Sun's corona, the faint outer part of our star's atmosphere. The point of light at right is a star picked up by the sensitive star tracker camera used primarily for navigation.

Pulsar Planets Confirmed

In 1990, Alexander Wolszczan of Pennsylvania State University discovered two planets orbiting the millisecond pulsar PSR B1257+12, but left open the idea that there might be a third planet in the system (see "Lost & Found: Pulsar Planets," June 1992). Writing in the April 22, 1994 issue of *Science*, he has now confirmed his original findings and expanded upon them.

The pulsar, an extremely small and dense neutron star, rotates 160 times a second, with its pulses so precisely timed they resemble the ticking of a clock. Changes in this apparent "ticking" led Wolszczan to his initial planet discovery; as the planets orbit the pulsar, the latter moves slightly, altering the arrival of the ticks on Earth.

Using a sophisticated mathematical analysis, Wolszczan unraveled the architecture of the pulsar system. Two planets have about three Earth-masses each and circle the pulsar with "years" of 66.6 and 98.2 days. The original third possible member (with a one-year period)



HIDDEN IN SAGITTARIUS, our nearest neighboring galaxy lies in nearly the same direction as the center of our own Galaxy. The globular cluster M54 may lie in the dwarf galaxy.

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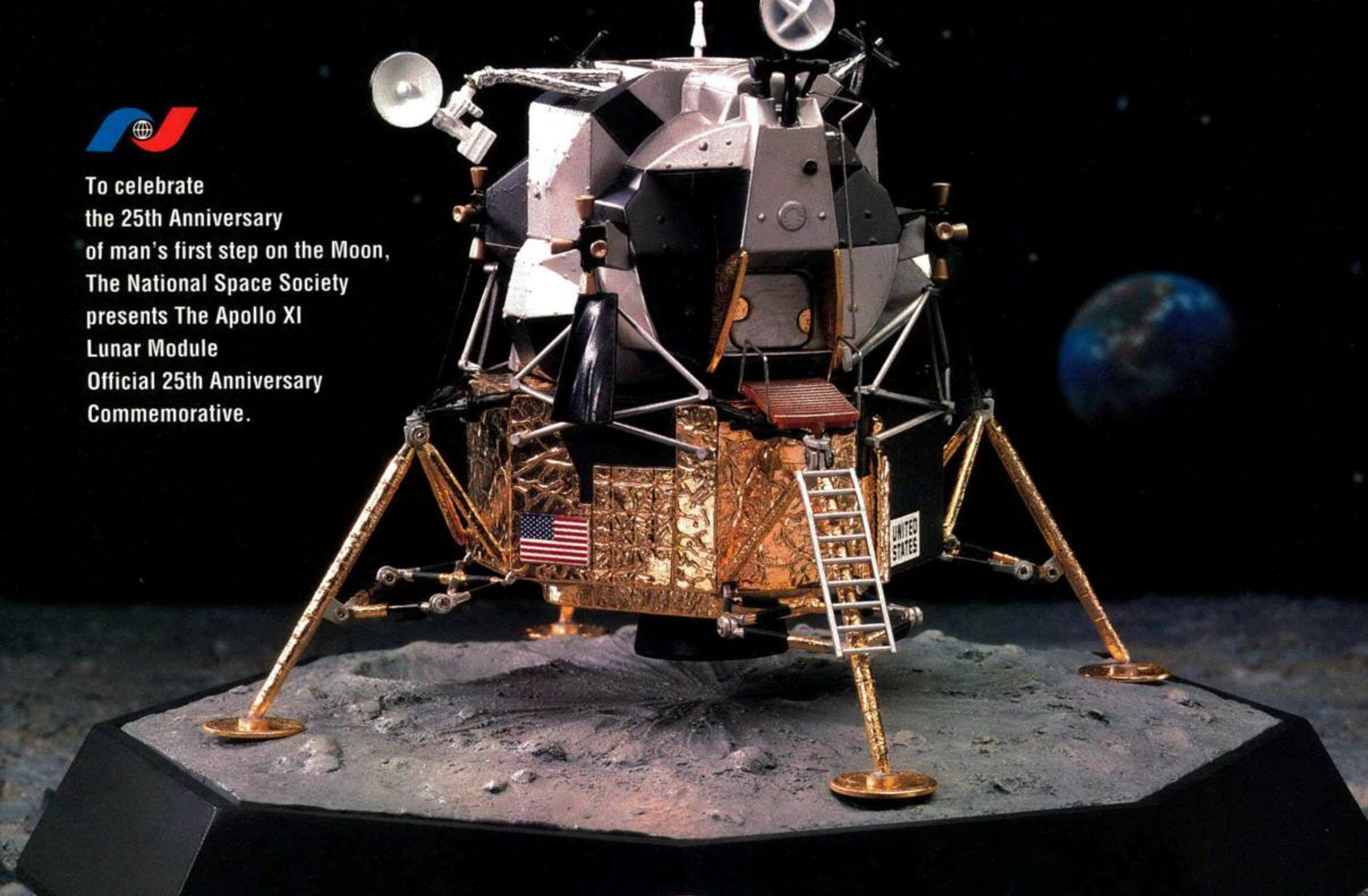

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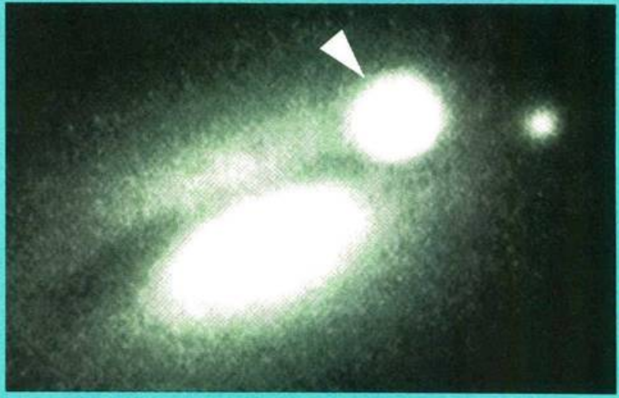
was not confirmed, but it appears that two more objects may be present. Wolszczan suspects a third body exists in the system with about the mass of Earth's Moon and a 25-day orbit. In addition, there may be a more distant object, size and mass undetermined, with a much longer period. — *Margaret Corbit*

SUPERNOVA IN THE VIRGO CLUSTER

A supernova exploded in March in the 10th-magnitude lenticular galaxy, NGC 4526. This galaxy lies 50 million light-years away on the outskirts of the Virgo Cluster. Richard Treffers, Alexei Filippenko, and Schuyler Van Dyk of the University of California at Berkeley and Michael Richmond of Princeton University discovered the supernova (SN 1994D) on an image taken March 7, 1994, as part of the Leuschner Observatory Supernova Search. The star rose to about magnitude 11.8 by late March and then started to fade in April. Spectral observations by other astronomers show that the supernova is a type Ia, which occurs when a white dwarf star explodes after gaining too much mass as it devours a companion star.



Schuler Van Dyk, U.C., Berkeley

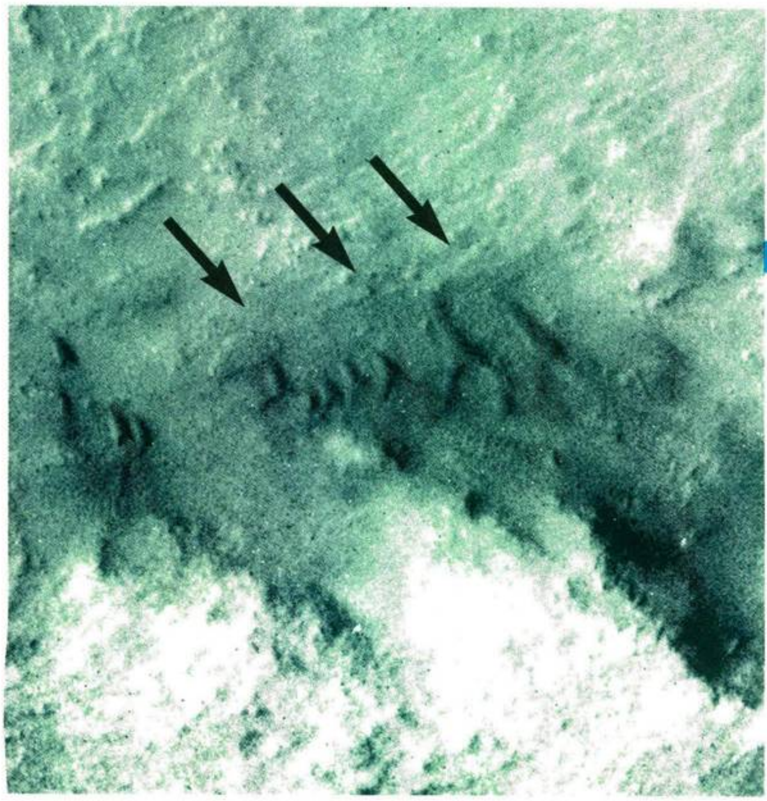
SUPERNOVA SN 1994D occurred in March 1994 in the lenticular galaxy NGC 4526, which lies in the Virgo cluster.

Mars Dunes Tell of More Dynamic Climate

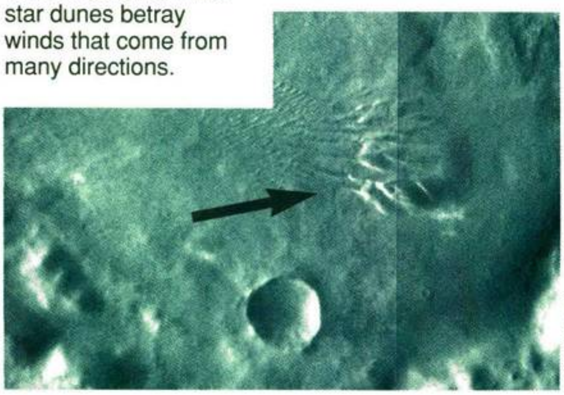
Two types of sand dunes common on Earth have finally been found on Mars, and the result is a more complex picture of Martian weather patterns than astronomers previously had. Planetary scientist Ken Edgett of Arizona State University finally found star dunes and linear dunes on Mars after poring over Viking images (see "Sands of Mars," June 1993).

Such dunes form on Earth as winds shift direction in response to the changing weather. Winds that blow from all directions about equally tend to pile up star-shaped dunes, while winds that alternate between two main directions create linear dunes.

Until Edgett's discovery, however, these dune patterns hadn't been found on Mars. Scientists believed this was because the Martian weather patterns are simpler than Earth's and winds at any one place blow mostly from one direction. Finding the new dune patterns indicates that in at least a few places, Martian winds are variable in direction, thus pointing out a more intricate picture for Mars weather.



NEW KINDS OF DUNES ON MARS indicate that its winds vary in ways that were unknown before. Linear dunes (below) suggest two alternating wind directions, while star dunes betray winds that come from many directions.



NASA/JPL/Arizona State Univ.

Supernova in a Starburst Galaxy

Discovering a supernova is usually big news because only 20 to 30 are witnessed each year. But when the supernova occurs in a rare type of galaxy, it's even more exciting. A team of six astronomers at NASA's Jet Propulsion Laboratory, NASA's Infrared Telescope Facility, and Caltech's Infrared Processing and

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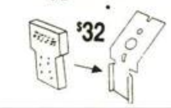

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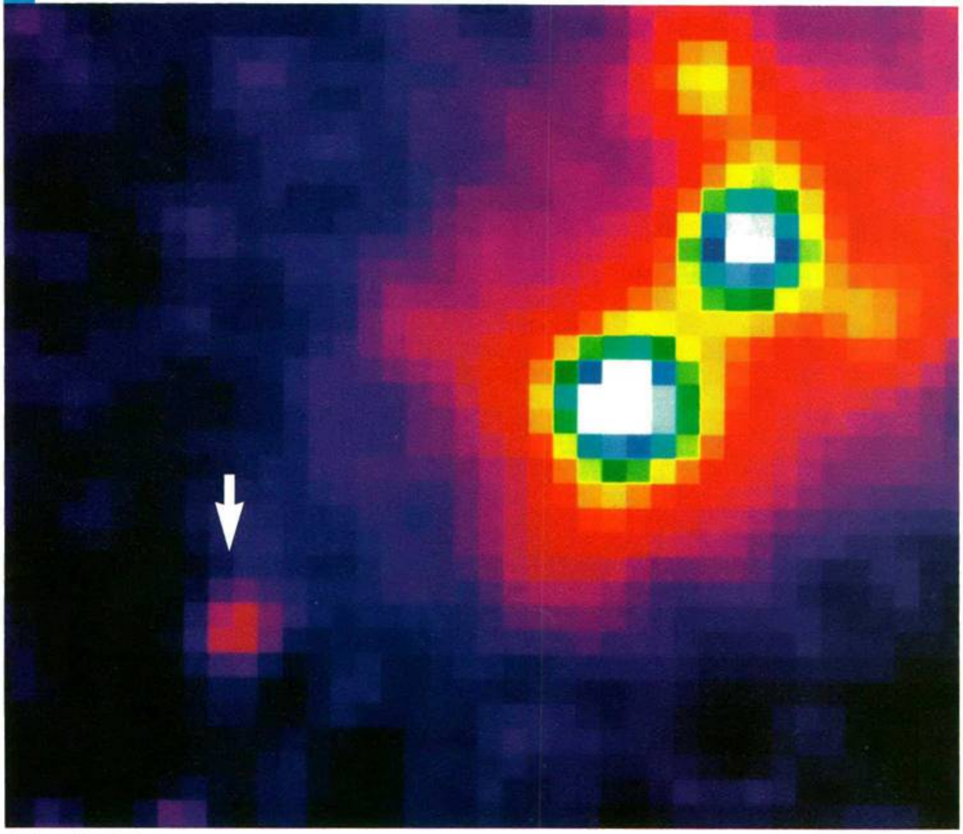
Analysis Center found a supernova (SN 1992bu) in the starburst galaxy NGC 3690 in the constellation Ursa Major. A starburst galaxy results when two galaxies collide, causing gas in the merged galaxy to form stars rapidly.

Thomas Jarret of IPAC spotted the star on an infrared image taken in March 1992 with the Infrared Telescope Facility on Mauna Kea in Hawaii. He concluded it was a supernova when he noticed the star had disappeared in an image taken in December 1993. The group had taken the images to determine whether massive stars or matter falling into black holes at the galaxy's center created the huge amount of energy radiated by the galaxy in the infrared. The 1992 supernova and supernova 1993G seen in visible light in this same galaxy lead the scientists to believe that the energy comes largely from massive stars.

SUPERNOVA 1992bu (arrow) exploded in March 1992 in the starburst galaxy NGC 3690. The white regions at upper right are in the galaxy's core.



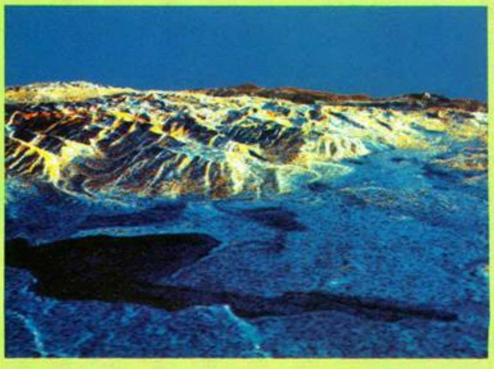
Jet Propulsion Laboratory

Red Storm Rising

Todd Clancy, a University of Colorado planetary scientist, reports that a large-scale dust storm is occurring on Mars. Clancy notes that observations made in January 1994 at millimeter wavelengths from Kitt Peak near Tucson, Arizona, showed the Martian atmosphere was relatively clear. However, observations made in early April showed the presence of substantial amounts of dust.

Mars will lie too close to the Sun for the Hubble Space Telescope to observe it until August. Partly as a result, Clancy is encouraging backyard astronomers to observe Mars, especially using deep blue and yellow color filters. Their observations will help astronomers ascertain the amount of obscuration on the planet's disk and track any changes. Report observations to the Marswatch Project, Jim

RADAR FROM ABOVE CAN ILLUMINATE Earth's surface in unique ways, allowing scientists to better understand environmental changes. Astronauts on the space shuttle Endeavour's April flight took these radar images of Mount Pinatubo in the Philippines (far right) and Mammoth Mountain in California (right). The red color on the high slopes of Pinatubo shows ash deposited during the 1991 eruption, while the dark drainages are mudflows that have continued to flood the river valleys after heavy rains. The view of the Mammoth Mountain region combines a shuttle radar image with an elevation map (heights are exaggerated two times). Blue represents smooth areas and yellow denotes rock outcrops with varying amounts of snow and vegetation. Mammoth Mountain appears at upper right, Crowley Lake is in the foreground, and Highway 395 crosses the middle of the image.



JPL

Bell, NASA Ames Research Center, Space Sciences 245-3, Moffett Field, CA 94035-1000. (For more on Marswatch, see AstroNews, July issue.)

Binary Pulsar Discovered in SMC

Astronomers studying the radio pulses emitted by a pulsar in a neighboring galaxy have discovered that it is orbiting a massive companion star, making this the first pulsar observed in a binary system outside our Galaxy. The discovery supports the idea that pulsars form in the aftermath of violent supernova explosions.

A research team headed by Victoria Kaspi of Princeton University discovered the pulsar, designated PSR J0045–7319, in the Small Magellanic Cloud, a satellite galaxy of the Milky Way located 184,000 light-years from Earth. It is the only radio pulsar known in the SMC, and only one similar system is known in the Milky Way Galaxy. The SMC pulsar emits one radio pulse every 0.9 second, corresponding to the time it takes the pulsar to rotate once on its axis.

The pulsar's companion star is a hot B star that glows at 16th magnitude. The pulsar orbits it every 51 days on a highly eccentric path, coming within five to six stellar radii of the companion at closest approach and swinging out to ten times that distance at its farthest.

Pulsars are rapidly rotating neutron stars that presumably form when a high-mass star explodes as a supernova. Most massive stars lie in binary systems, however, and the explosion

AMATEUR NEWS

A Cosmos Close Enough to Touch . . .

Two students at Oil City High School in Oil City, Pennsylvania, were instrumental in obtaining the earliest pictures of April's supernova in M51. Working through a program administered by the University of California at Berkeley called "Hands-On Universe," Heather Spence and Melody Tartara found the brightening star on images taken at Berkeley's Leuschner Observatory. The two were working through Hands-On's computer network to access CCD photos taken at the observatory.

Spence and Tartara had requested the images be shot on March 28 and 30 as part of a supernova search. Unfortunately they didn't notice the supernova until April 6th, five days after its announced discovery. The pictures do, however, provide important data about the exploding star's characteristics. Considering the scale of Hands-On's survey effort, this near-discovery shouldn't come as a surprise.

Several hundred images of the sky are taken each night with the observatory's 30-inch telescope. After the pictures are shot, they are downloaded to the Hands-On network, where teams of high school students from all over the country search for supernovae in galaxies, variable stars, or new asteroids and comets. Students can either work with pictures shot on a schedule set by observatory staff or, as the Oil City team did, request certain objects be imaged at selected times.

Hands-On Universe, now in its third year, will be expanded to still more high schools later this year. A version is even being readied for science museums. Given enough funding, organizers also hope to include junior high schools and colleges across the United States.

Of Starspots and Virtual Skies

Feel up to doing some research on Mt. Wilson? How about producing a planetarium show at the National Air and Space Museum? Well, Smithsonian Research Expeditions, a service of the Smithsonian Institution, is offering workshops this summer at both locations that just might involve you.

During two one-week Mt. Wilson sessions (July 9-16 & September 10-17), volunteers will be working observatory staff on projects looking for "starspots" on nearby Sun-like stars, using the 60-inch reflector. A $1,172 fee for each session includes board; food is extra.

The planetarium workshop (August 7-20) has five slots open to anyone with photographic, scriptwriting, science education, art, audio-visual, or musical experience. Working with NASM staff, the team will produce 10- to 20-minute multimedia planetarium shows. A $1,512 fee includes accommodations, transportation to and from the Museum, as well as a welcome and farewell dinner.

To get workshop registration forms, call Smithsonian Associates at (202) 287-3210.

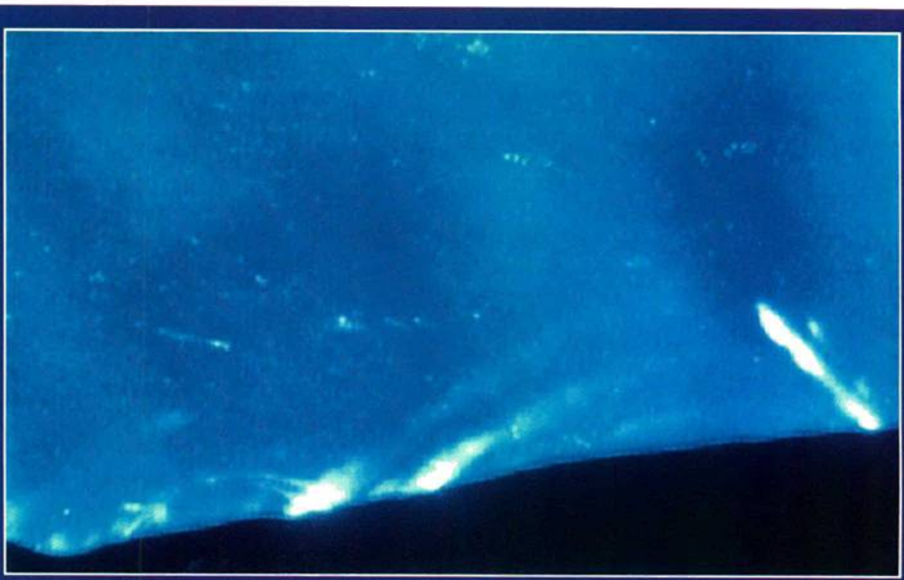
Europeans Hold CCD Confabs

Not to be outdone by their charge-coupled American neighbors, Europeans held two workshops on CCDs last October, one high in the Austrian Alps at St. Sebastian, the other in Winchester, England. The Austrian gathering attracted 41 people from all over Europe, while Great Britain's first workshop on CCDs drew 95 interested participants.

The Austrian meeting, organized by Gunter Eder, featured talks given by amateurs on everything from home-brewed image-processing programs to using a CCD for precise photometric measurements. Austrian amateur Heinz Scsibrany showed results of imaging faint galaxies in the Milky Way's Local Group. To take advantage of the Alps' steady atmosphere for imaging, a 14-inch Schmidt-Cassegrain was made available to amateurs for CCD work on both evenings.

The British workshop, put together by Ron Arbour of the British Astronomical Association, featured a keynote talk by a Hubble Space Telescope investigator who used the telescope for faint object astrometry, along with amateur presentations about building a CCD camera, using CCDs for spectrographic analysis, and coupling filters to cameras for deep sky research. A display area included vendor tables as well as amateurs showing off CCD cameras, latest images (some showing stars down to magnitude 20), and image-enhancement software.

For information concerning any follow-up meetings this autumn, write Maurice Gavin, 79 Ardrossan Gardens, Worcester Park, Surrey KT4 7AX, England. — *Maurice Gavin* normally ejects the pulsar from the system. Only under special circumstances does the newly created pulsar remain with its companion, and in those cases the pulsar is thrown into a highly eccentric orbit. Thus the existence of the PSR J0045–7319 system and the rarity of similar systems attest to the violent nature of the events that produce pulsars.


L. November and S. Koutchmy

A DARK VOID RISES above a small prominence (right) in this image of the Sun's corona taken during the July 1991 total solar eclipse. The irregular dark shape at bottom is the Moon's limb.

Eclipse Update

The total eclipse of July 1991 was billed by the media as "The Eclipse of the Decade." But with the annular eclipse of January 1992 and the recent one in May, the July 1991 eclipse has become a distant memory for some. Not, however, for the professional astronomers who continue to study the images they took of the Sun's corona from Mauna Kea in Hawaii. Serge Koutchmy of the Institut d'Astrophysique in Paris and a team of 16 colleagues from the United States, France, and Canada used the Canada-France-Hawaii telescope to view fine-scale structures in the corona and to watch their motions. They also detected voids in the corona, associated with prominences, loops of gas that extend into the corona from the atmosphere. Solar astronomers had detected cavities in the corona before, but the new high-resolution observations show looplike structures in the voids. Such small-scale features are key elements in transferring magnetic energy from the Sun's atmosphere to the corona and thus heating the corona to over a million kelvins.

India to Build its Own VLA

India has begun to build a 30-dish radio telescope array that will have the same high-resolution performance as the Very Large Array radio telescope in New Mexico. The telescope's dishes will each be 45 meters in diameter, significantly larger than the VLA's. (Unlike the VLA's antennas, however, those in the Indian array will not be individually moveable.)

The instrument is scheduled for completion in late 1994 or early 1995. Astronomers will use it to study hydrogen clouds in the early universe, from which they believe the first galaxies formed. They also plan to search for pulsars with extremely fast rotation periods. The telescope, located at a latitude of about 19° north in the Rajasthan Desert east of Bombay, will be able to view clearly most of the Milky Way's length.

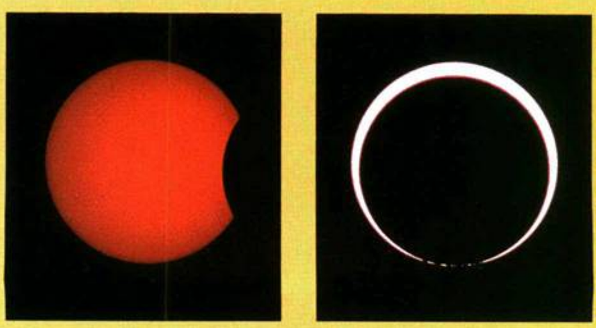
An important feature of the instrument is its low cost: $15 million in all. The builders achieved this by simplifying the design and using local suppliers. For example, the dishes are made of open wire mesh instead of solid metal, and most parts are manufactured in India.

GOES Went

The successful launch of GOES-8, the new-generation Geostationary Operational Environmental Satellite, on April 12 injected life into a program that had been near death for several years. Before the launch, the United States had been relying on GOES-7 and a Meteosat satellite on loan from the European Space Agency after a prior GOES satellite was destroyed during its 1986 launch. The GOES-7, while still working well, is two years past its design lifetime and running out of fuel.

GOES-8 will gather data continuously instead of about one-sixth of the time because it is stabilized in three axes, as opposed to its spin-stabilized predecessors. Newly developed sensors will measure the temperature and moisture content in clouds at heights between 12,000 and 60,000 feet. All this translates into GOES-8's ability to pinpoint the landfall of major storms and hurricanes to within about a mile some five times better than its earlier cousins. If all goes according to plan, GOES-8 will be fully checked out by October and take its place at 90° east longitude. ☐

THE ANNULAR ECLIPSE OF MAY 10, 1994, delighted viewers from Baja California to New England to Morocco. The Moon's disk slowly crept across the Sun until it formed a "ring of fire." Extensive coverage will appear in the September issue.


Both photos by Alberto Levy

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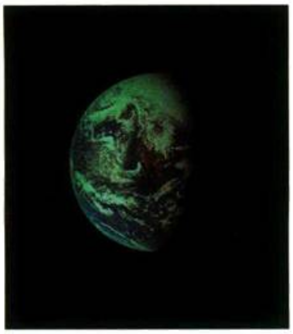

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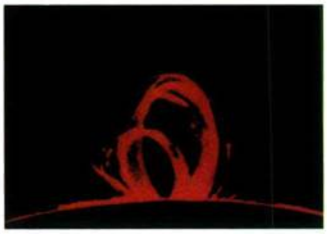

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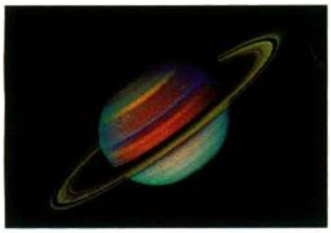

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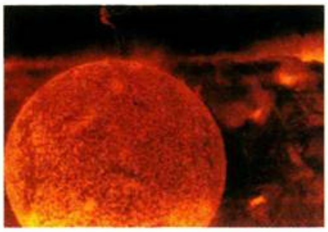

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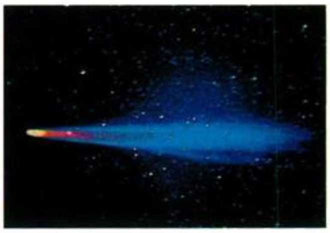

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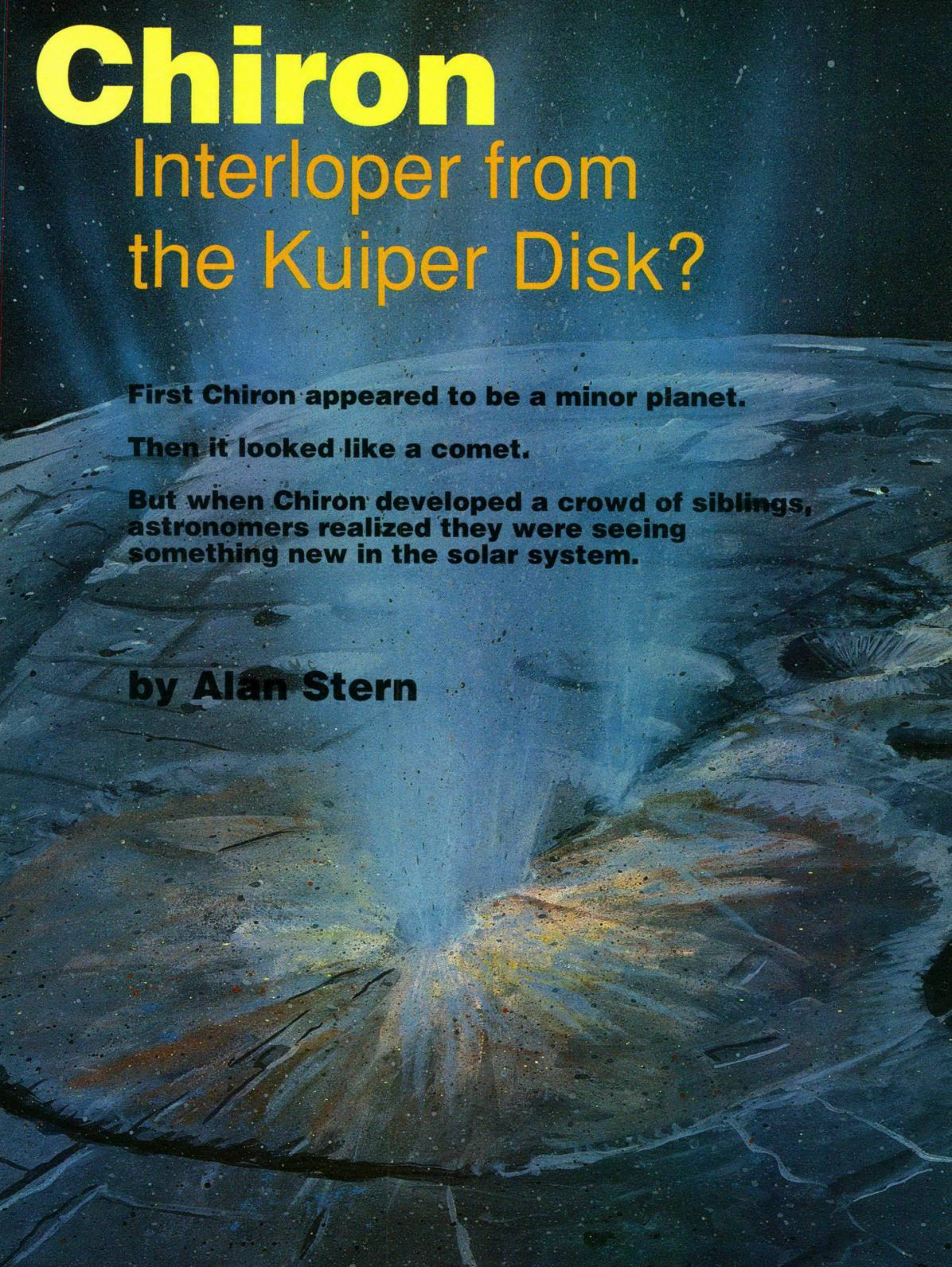
Chiron

Interloper from the Kuiper Disk?

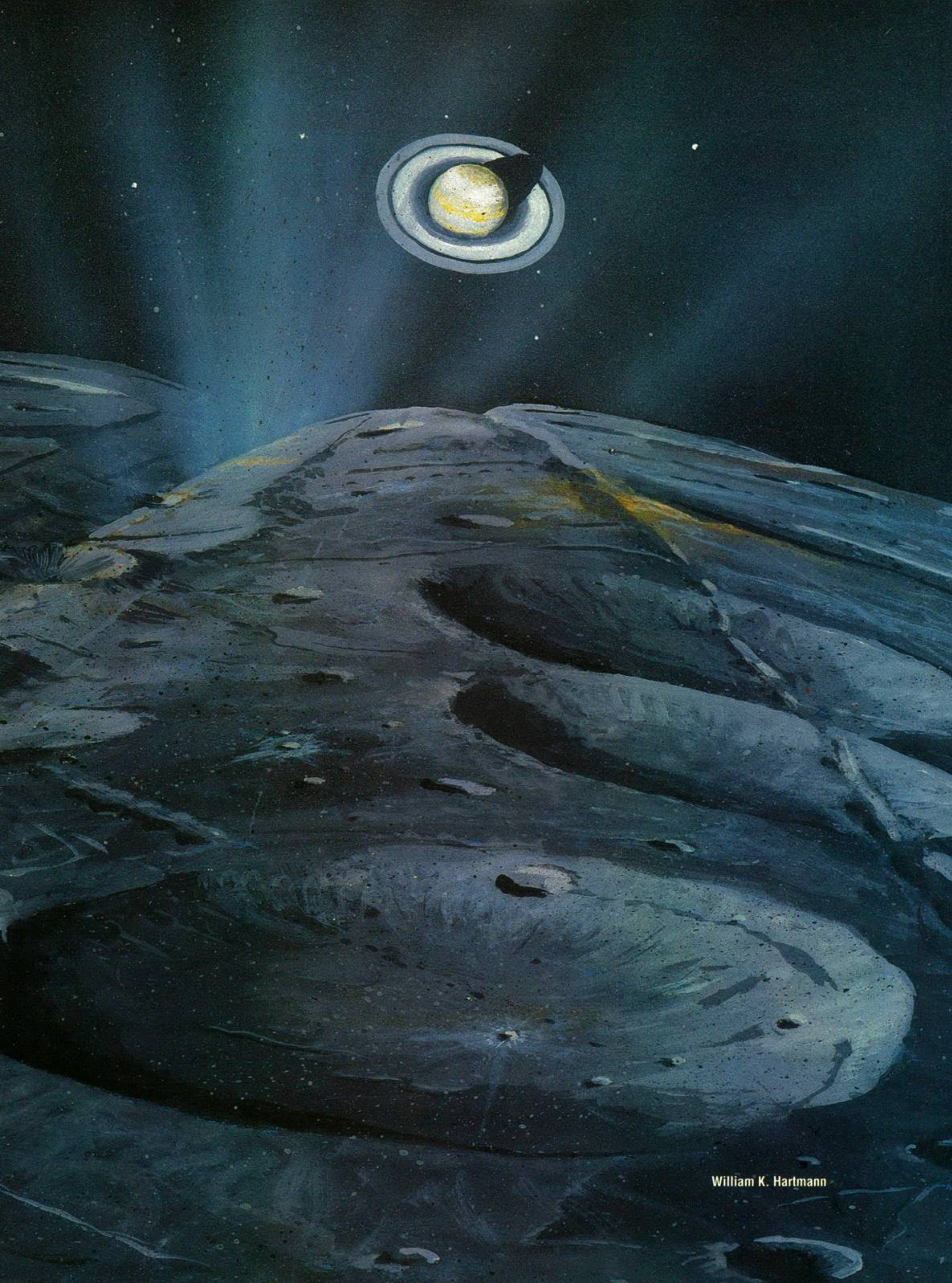


First Chiron appeared to be a minor planet.

Then it looked like a comet.

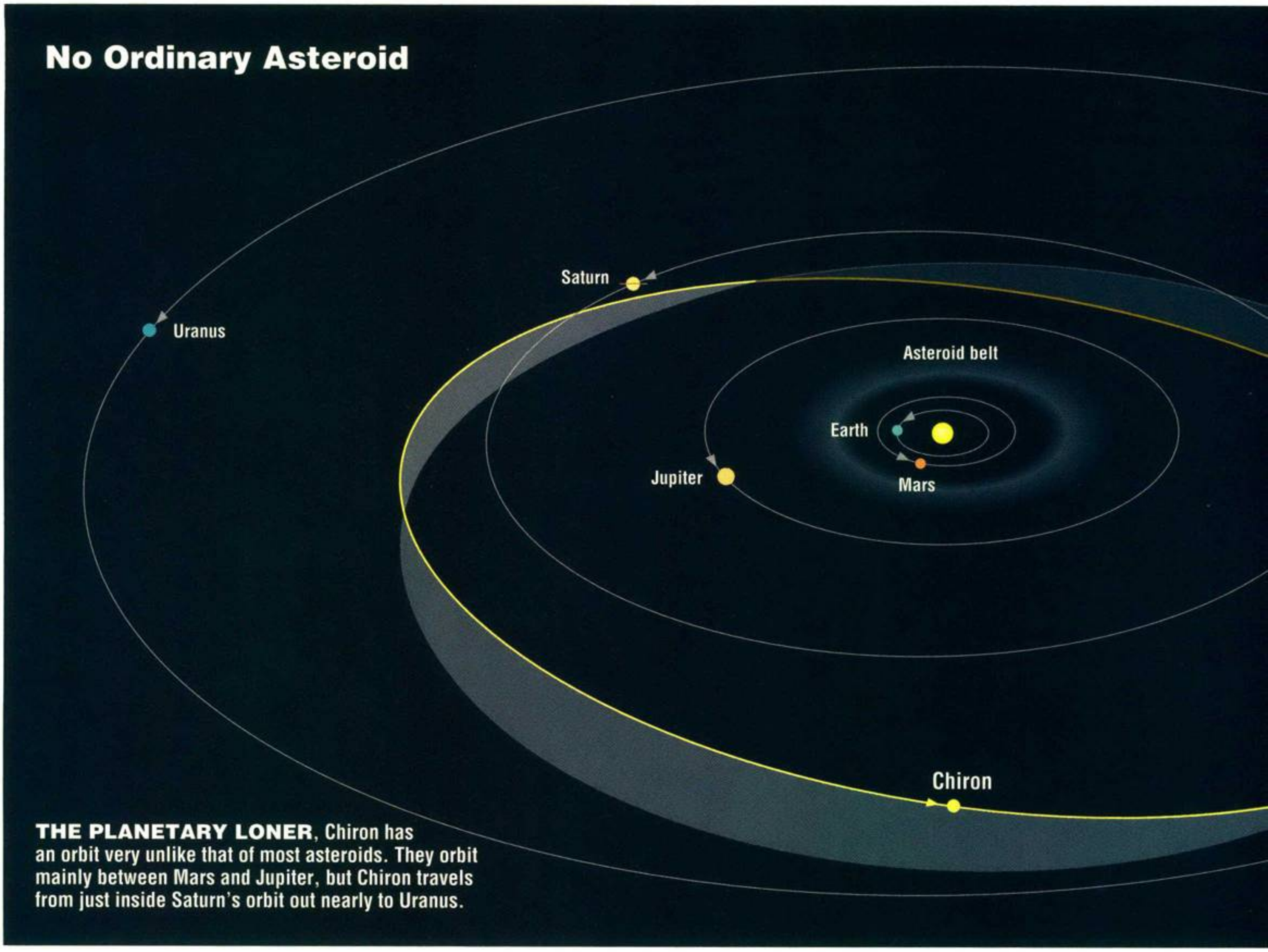
But when Chiron developed a crowd of siblings, astronomers realized they were seeing something new in the solar system.

by Alan Stern



William K. Hartmann

No Ordinary Asteroid



THE PLANETARY LONER, Chiron has an orbit very unlike that of most asteroids. They orbit mainly between Mars and Jupiter, but Chiron travels from just inside Saturn's orbit out nearly to Uranus.

Palomar astronomer Charlie Kowal didn't intend to discover a new kind of object. The short, faint streak he found in 1977 on a photographic plate of a region of sky in Aries received the routine designation given to a new minor planet, 1977 UB in this case. And once enough observations yielded an orbit for the new object, the Minor Planet Center officially labeled 1977 UB as asteroid 2060 Chiron.

But calling Chiron an asteroid left many astronomers uneasy. After all, asteroids are supposed to reside mainly between Mars and Jupiter. What was one doing with a 51-year orbit that reached from inside Saturn's orbit outward almost to Uranus? Could Chiron be a comet?

By conventional comet standards, the short answer was "probably not." Bill Hartmann of the Planetary Science Institute took Chiron's apparent brightness and assumed a surface reflectance of about 10 percent, typical of most comets. This yielded an estimated diameter for Chiron of between 130 and 400 kilometers. About the same time, University of Arizona astronomer Larry Lebofsky and his colleagues studied Chiron's infrared spectrum and derived a diameter near 180 km. Later measurements by other groups using spacecraft and ground-based facilities indicated Chiron is most likely between 200 and 350 km in diameter. That's *big*. If you compare it to the 3 to 10 km diameters of many comets, Chiron was a monster. It was like an Empire State Building towering over suburban homes.

Clearly, Chiron didn't seem to fit into any existing category. It was too small to be a planet, too distant to be a conventional asteroid, and too large to be a typical comet. What made classification even more difficult was that Kowal had found Chiron as a part of a deep survey that reached magnitude 20 in a wide area centered on the ecliptic. With all his careful work, Kowal had found only this one object in the entire outer solar system.

Well all right, astronomers reluctantly concluded, maybe 2060 Chiron is just an odd bird.

A Stranger from a Strange Land

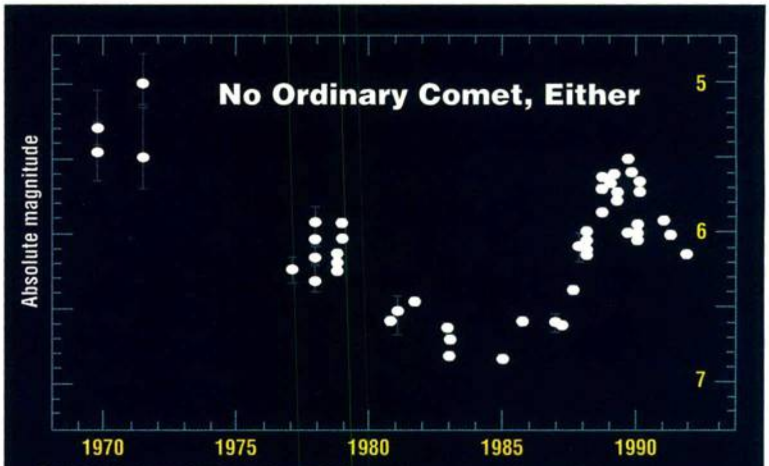
During the first decade after its discovery, Chiron remained a curiosity. Astronomers learned only a few things more about it. For example, they found that Chiron's present orbit is unstable and probably short-lived. Also, they learned that Chiron rotates in 5.92 hours and displays a regular 9 percent change in brightness. This indicates that Chiron either has subtle spots or is not quite round, or both. These facts were useful but not very revealing of Chiron's nature. Fortunately, begin-

ning just after the 10th anniversary of its discovery, more interesting results began to emerge.

The first real break came when Dave Tholen of the University of Hawaii detected a sudden brightening of Chiron in early 1988. With colleagues Bill Hartmann, Karen Meech, and Dale Cruikshank, Tholen quickly confirmed that Chiron's brightness had nearly doubled. But at its great distance from the Sun — a dark and chilly 13 astronomical units — what could have caused this? Had Chiron developed a coma? Had it been struck by a meteorite, splashing some bright material on its surface? Had a geyser gone off, coating the surface with bright material?

Often when astronomers can't say what is going on, they can at least rule out some things that aren't. With that in mind, in 1988 I undertook a project to ask if it was possible Chiron's surface could be active in the same way the surface of a conventional comet is, with surface ices sublimating (steaming off) to form a tenuous coma. To answer this, I constructed a computer model that first estimated the temperature of Chiron's surface and then calculated the sublimation rates of various likely ices.

What I found was twofold. First, ordinary water ice, which fuels the production of a coma in most comets,



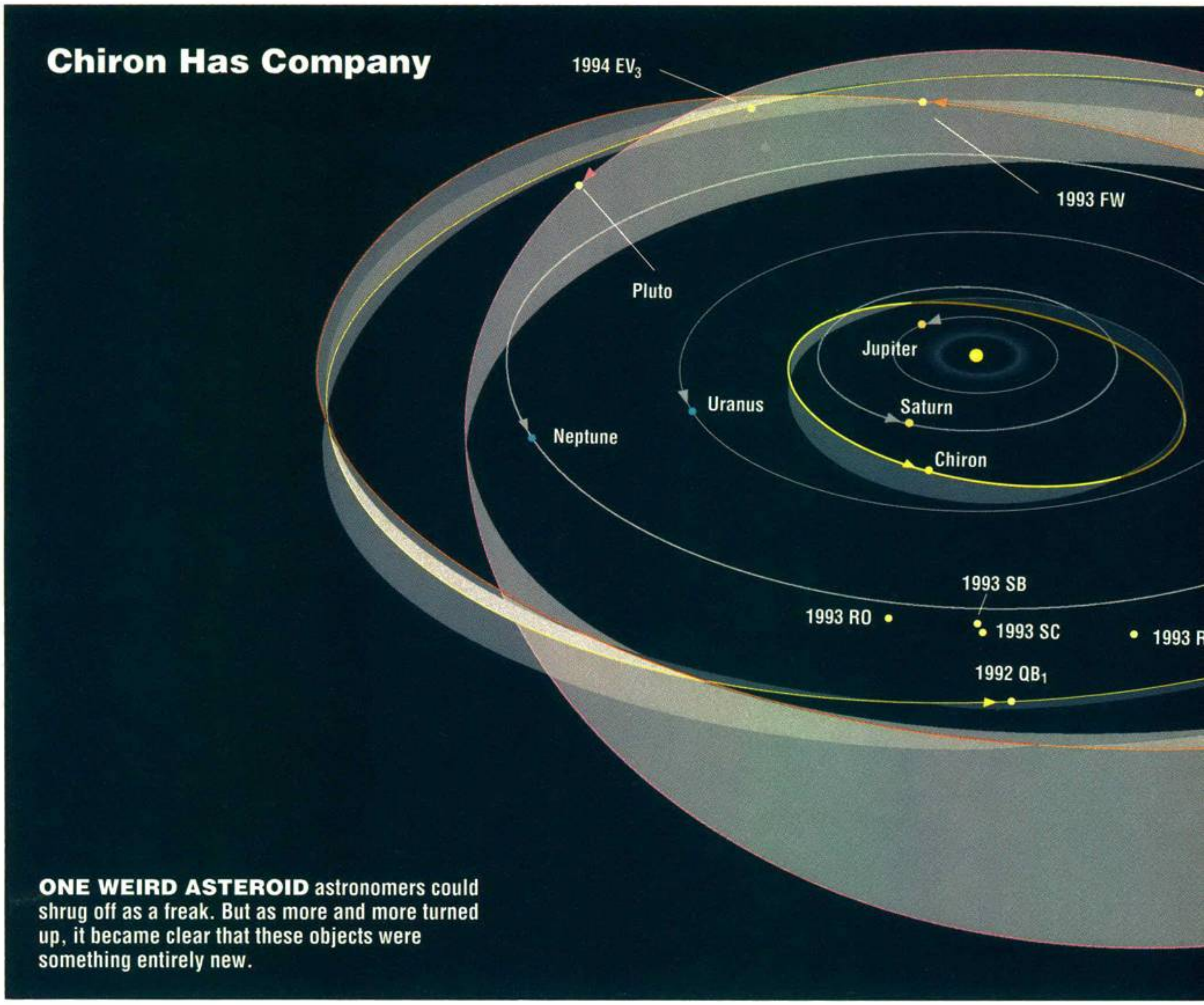
CHIRON'S CHANGING BRIGHTNESS over the years told astronomers that something really odd was going on — because Chiron was too far from the Sun to brighten like an ordinary comet.

won't do at Chiron. Its orbit simply lies too far from the Sun for water ice to be warm enough to sublimate. Instead, something much more volatile is required, like carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), or nitrogen (N_2) ice. Even more interesting, it turned out that if Chiron had spent any significant fraction of the age of the solar system closer to the Sun than now, it would have lost so much ice that it couldn't be active today. Apparently either Chiron is a recent arrival from a more distant region of the solar system or it brightens for reasons that have nothing to do with surface ice sublimation.

The first new clue to narrow the options came in 1989 when Karen Meech, with Mike Belton of the National Optical Astronomy Observatories, succeeded in detecting a tenuous coma of ice and dust surrounding Chiron. This coma, which has at times swollen to more than 320,000 km in diameter, proved that some mechanism (probably sublimation) was ejecting ice and dust particles from Chiron's surface. Then in 1990, a team consisting of Bobby Bus and Ted Bowell of Lowell Observatory and Mike A'Hearn of the University of Maryland detected the presence of cyanogen gas (CN) in Chiron's coma. Although cyanogen is only a trace species in cometary atmospheres, it's easier to detect than more common coma species because it fluoresces readily in sunlight. Cyanogen proved that Chiron's coma contained gas as well as the previously detected ice and dust.

Since 1990, continued monitoring has revealed that over weeks or months, Chiron brightens and dims by 30 to 50 percent. Presumably, this is because the amount of material in the coma varies. Detailed photometric studies by Dave Jewitt at the University of Hawaii, Jane Luu at the University of California-Berkeley, Bonnie Buratti and Scott Dunbar of the Jet Propulsion Laboratory, and Robert Marcialis of the University of Arizona have even detected what seem to be random night-to-night and hour-to-hour fluctuations in the coma's brightness of a few percent.

Most interesting, a team of astronomers led by Bobby Bus (now at MIT) analyzed prediscovery images of Chiron taken between 1969 and 1972. Bus and his co-workers found that Chiron was brighter back then than it has been since! This was a surprise because during that period Chiron was near its aphelion at 19.5 AU. Whatever drives Chiron's activity is capable



Chiron Has Company

ONE WEIRD ASTEROID astronomers could shrug off as a freak. But as more and more turned up, it became clear that these objects were something entirely new.

ASTRONOMY: Phil Kirchmeier

of operating not just at 13 AU, but even at nearly 20 AU, where conditions are much colder.

Since carbon dioxide ice won't sublimate this far from the Sun, this rules it out as the surface ice that caused the aphelion activity. With only carbon monoxide, methane, and nitrogen ice remaining as candidates, Chiron's surface ices more and more begin to resemble Triton's and Pluto's than a conventional comet's.

A second implication of Chiron's sporadic activity is that its surface is probably covered by some kind of darkish mantle or crust. This prevents much of the ice from being active and allows only episodic eruptions, perhaps from isolated vents or fissures. Calculations show that only 0.1 to 1 percent of Chiron's surface has to be active in order to supply the observed coma.

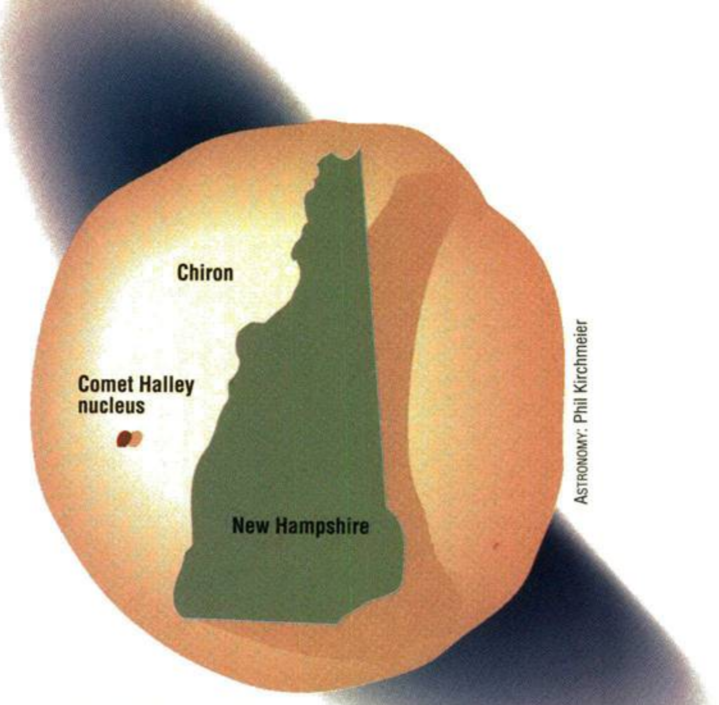
Putting together everything now known about Chiron, it seems to be an icy object the size of a small state traveling between the outer planets in an orbit it cannot have occupied for more than a tiny fraction of the age of the solar system. Active at large solar distances, Chiron seems to contain exotic, low-temperature ices near its surface, perhaps with a thin veneer of silicate dust or organic material covering most of it. If a spacecraft someday flies past Chiron (see page 32), it might see Triton-like geysers shooting hundreds of kilometers into the sky, episodically resupplying a coma that varies as the surface vents cough and sputter.

How Many More?

But Chiron's mere existence raises a puzzle. Why aren't there lots more of them between Saturn and Uranus?

The simple answer is that the gravitational influences of Jupiter, Saturn, Uranus, and Neptune conspire to remove any object that orbits between them. In fact, computer simulations of the outer solar system by Canadian dynamicists Bret Gladman (now at Cornell) and Martin Duncan of Queen's University show that objects in orbits between any of the giant planets usually disappear quickly in no more than 1 or 2 percent the age of the solar system. Simulations of Chiron's specific orbit by British dynamicists Mark Bailey of the University of Manchester and Gerald Hahn (now at Uppsala University) indicate that Chiron's orbit is unstable on time scales of a few million years. This agrees nicely with the view that Chiron could not still have surface ices and be active if it had always been in its present orbit.

So one wonders: where did Chiron come from? And why should it, just now, be in a short-lived orbit? To answer that we must travel back to 1951 and a volume titled *Astrophysics.* That book, edited by J. Allen Hynek, surveyed where astronomy stood at mid-century and where astronomers thought it was going. In it Gerard Kuiper wrote a prescient article on the state of solar system science. It's been said that Kuiper was two-thirds of



ASTRONOMY: Phil Kirchmeier

CHIRON'S A GIANT compared to comets such as Halley. It has a diameter roughly the size of New Hampshire.

the entire planetary astronomy community in the 1940s; he was clearly the right person to write the article. He had just discovered the satellites Miranda (of Uranus) and Nereid (Neptune), and the atmosphere of Saturn's moon Titan.

Kuiper discussed a remarkable fact — that the solar system does not simply dwindle away at great distances from the Sun. Instead the planetary system appears to just quit, as if there were a sharp edge or discrete boundary out beyond 30 AU. Kuiper concluded this was most likely because no giant planet had had the time to form beyond Neptune during the 5-billion-year age of the solar system. Kuiper saw no reason why the solar nebula (from which the planets were constructed) should end at 30 AU, so he postulated that a disk or belt of leftover material, the makings of additional planets, probably lay beyond Neptune.

Kuiper's hypothetical disk was largely forgotten for decades. Astronomers' interest in the idea, however, reawakened in the early 1980s. This occurred when University of Montevideo (Uruguay) theorist Julio Fernandez suggested that most short-period comets might come from Kuiper's reservoir — provided small, unseen planets embedded in the reservoir were numerous enough to jar these comets loose from time to time. By the late 1980s, with fast computers at their disposal, Martin Duncan, plus Thomas Quinn and Scott Tremaine of the University of Toronto demonstrated through simulations that it was unlikely that the short-period comets could be explained *without* Kuiper's disk.

What Duncan, Quinn, and Tremaine found was that the low orbital inclinations of the short-period comets require these comets to originate in a flattened disk. Further work by others showed that if this disk originally extended inward to Neptune's orbit, the gravity of the four giant planets would "erode" the disk, roiling its inner edge and pulling comets in to where we might detect them. Although this work involved some shortcuts, it convinced many astronomers that Kuiper's original suggestion was right.

By coincidence, the stage for accepting the Kuiper disk had been quietly set a few years before. In 1983, the Infrared Astronomical Satellite discovered disks around a host of nearby main-sequence stars like Beta Pictoris and Vega. Paul Weissman, of the Jet Propulsion Laboratory, and others convincingly argued these dust disks were created by comets and asteroids colliding in orbit around their parent stars, which isn't very dissimilar from what Duncan, Quinn, and Tremaine were proposing.

While theorists debated and analyzed the results, it became the observers' turn. The race was on to find the Kuiper disk.

But it's not that easy. Calculations said there might be 100 million or more comets beyond 40 AU, but they are very dim — none brighter than 28th or 29th magnitude. This is too faint for reliable detection from the ground today, although plans are afoot to try with the repaired Hubble Space Telescope. Instead, observers pinned their hopes on finding the larger (but much rarer) objects that might be much brighter — perhaps 23rd or 24th magnitude. (Keep in mind that 24th magnitude is 10,000 times fainter than Pluto.) The technique most often adopted involves making deep images of the dark (New Moon) sky using photographic plates or CCD arrays. The best areas to image are the areas opposite the Sun on the sky, where an object is brightest and its apparent motion allows its distance to be determined easily.

Several groups were onto the hunt in earnest. First they searched to 21st magnitude, then to 22nd, and then 23rd. Nothing turned up. Finally in August 1992, Dave Jewitt and Jane Luu of the University of Hawaii discovered a slow-moving object at magnitude 23.5. It turned out to lie at a distance of 44 AU. Dubbed 1992 QB_1, the object appears to orbit the Sun in a nearly circular orbit that lies within a few degrees of the ecliptic. Based on its assumed surface reflectivity of a few percent, "QB_1" is likely to be 200 to 250 km in diameter.

Six months later, Luu and Jewitt discovered a second Kuiper disk object, 1993 FW. And six months after that, Luu and Jewitt found two more bodies beyond 30 AU: 1993 RO and 1993 RP. These were followed by still another two (1993 SB and 1993 SC) found by a British group led by Iwan Williams of Queen Mary College. (The latter four either belong to the Kuiper disk or form a group of asteroids orbiting the Sun at Neptune's distance, 60° ahead of the planet.) Finally, just this past March, Luu and Jewitt picked up another pair, 1994 ES_2 and 1994 EV_3, at distances of 45 and 46 AU.

All these new objects have brightnesses indicating they are between 50 and 500 km in diameter. Since all have been found in a search area that totals barely 2 square degrees and there are over 1,000 square degrees of sky left to search along the ecliptic, it's reasonable to predict that between 1,000 and 10,000 QB_1s lie in the Kuiper disk region between 35 and 45 AU. Additional objects may lie farther out.

Are the QB_1s the tiny stillborn objects that, as Kuiper suggested, never had the time to accumulate into another Neptune? Are they precursors of the host of Pluto-Triton "ice dwarfs" predicted (separately) by myself and Bill McKinnon of Washington University to lie in the more distant outer solar system? (See "Where Has Pluto's Family Gone?" September 1992.) Are the QB_1s the kinds of objects now colliding in the dusty disks around stars like Beta Pictoris, Vega, and Fomalhaut? I don't know, but I hope we'll have the answers to many of these questions before the last night of the 20th century is done.

A Mission to Chiron?

At present Chiron is nearing its perihelion inside Saturn's orbit, but is still no brighter than 16th magnitude. And although it is about as close to Earth as it will ever get in our lifetime, its apparent diameter is less than 1/20 of an arcsecond. These circumstances make it almost impossible to do more than crudely characterize Chiron's bulk properties, even with the best ground-based and space-based observatories.

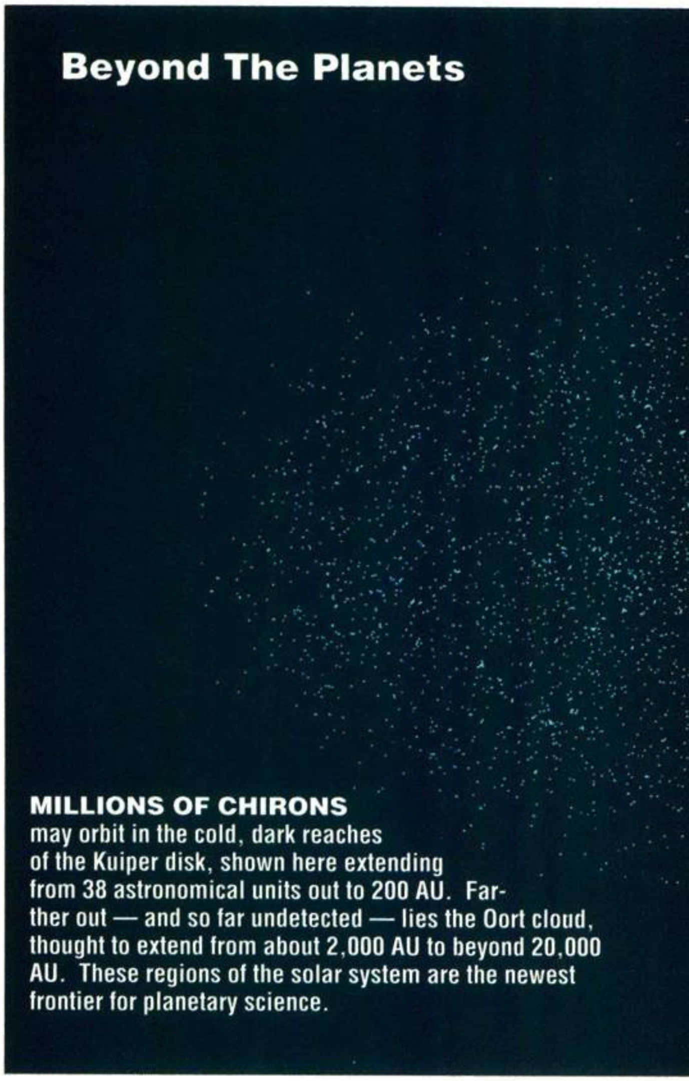
Without a mission to Chiron, there's no real prospect we will ever see its surface features, know the true source of its activity, measure its mass and density, or probe the composition of its atmosphere. Fortunately, there now appears to be a way to reconnoiter Chiron — and gain a glimpse of what the 10,000-odd QB_1s of the Kuiper disk are really like.

Recently NASA studied whether spacecraft such as that planned for the Pluto Fast Flyby (see "Pluto and Charon," January 1994) could carry out missions like a Chiron flyby. The answer was yes. The biggest change to the spacecraft is the addition of dust shields to guard against impacts by high-velocity coma grains.

Like the Pluto Fast Flyby, a Chiron Reconnaissance Flyby would carry a sophisticated CCD camera and infrared mapper. Likely additions to the payload would include an impact analyzer to study the composition of grains in Chiron's coma and a mass spectrometer to sniff out the composition of Chiron's atmosphere. Careful radio tracking of the spacecraft would accurately measure Chiron's mass. Along with a volume derived from imaging, mass measurements could determine Chiron's density, revealing whether the object is more like a giant, fluffy comet or a denser ice dwarf like Pluto or Triton.

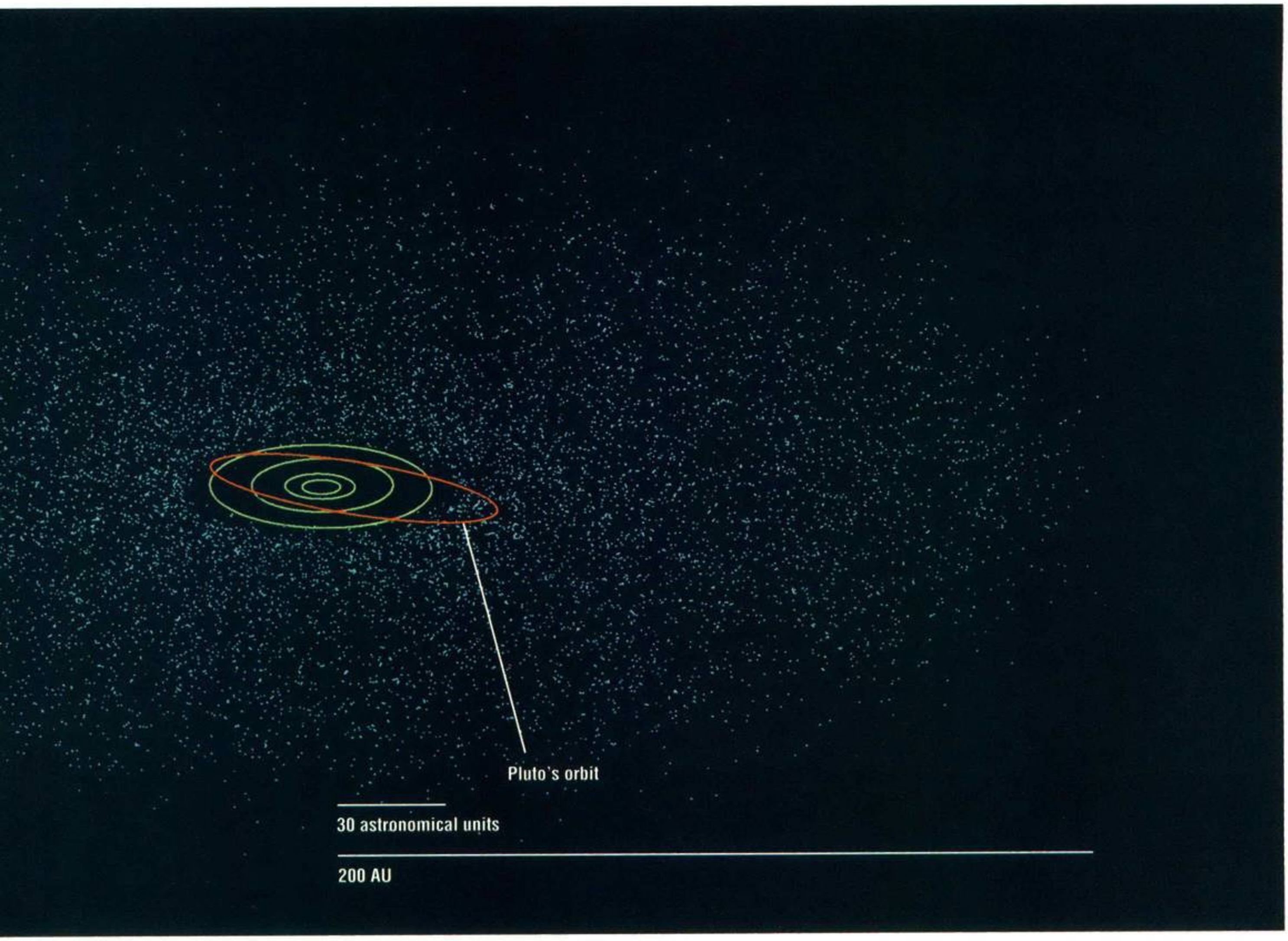
Mission studies show that the craft could reach Chiron 4.3 years after launch on a Titan IV rocket, or 7 years after launch on a much less powerful (but much less expensive) Atlas II. In either case, the trajectory would carry the spacecraft directly from Earth to Chiron, avoiding the expense of a Jupiter flyby. Cost estimates place the mission in the newly defined Discovery class: about $150 million, plus launcher.

If NASA does the lightweight Pluto Fast Flyby, then a follow-up Chiron reconnaissance mission would make good use of existing designs — and give humans our first peek at what seems to be a long-wandering beast from the Sun's icy Kuiper disk.



Beyond The Planets

MILLIONS OF CHIRONS may orbit in the cold, dark reaches of the Kuiper disk, shown here extending from 38 astronomical units out to 200 AU. Farther out — and so far undetected — lies the Oort cloud, thought to extend from about 2,000 AU to beyond 20,000 AU. These regions of the solar system are the newest frontier for planetary science.



Harold Levison, Southwest Research Institute

What's important here is that astronomy appears to have discovered another major piece of the solar system's architecture: the Kuiper disk. How massive is it? How far out does it stretch? Are there gaps in the disk or is it continuous? What is the range of sizes for objects in the disk and what are they made of? Are planets slowly building today beyond Neptune and Pluto? All these questions are wide open today.

These are special times for planetary scientists. I like to draw an analogy. In regard to the Kuiper disk, we in 1994 stand about where astronomy did in 1807 regarding the asteroid belt — when just Ceres, Juno, Pallas, and Vesta had been discovered. A whole new frontier is opening up. This time, however, there are 10,000 QB_1s (perhaps with a few even larger ice dwarfs too) and 100 million comets waiting to be cataloged and studied.

Fences Down: Cosmic Connections

As the history of Chiron shows, over the past two decades life has grown a lot more complicated for planetary scientists. Many formerly tidy distinctions among types of objects have become blurred. We now know comets can turn off and look like asteroids and that some apparent asteroids can become active and resemble comets. Comet Shoemaker-Levy 9's orbit around Jupiter shows that giant planets can trap comets and then rip them apart by tidal forces and perhaps make them into gossamer-thin planetary rings. We now know there is yet another asteroid belt or disk beyond Neptune. Faced with a continuum of objects, we're struggling to draw boundaries between comets and asteroids, Chirons and comets, and planets and ice dwarfs.

Although it received its name before anyone knew what it was, Chiron appears well-named. The mythological Chiron was a centaur, a beast neither man nor animal but something in between. The astronomical Chiron is likewise neither the lonely giant comet nor the rogue asteroid it was perceived to be in 1977. Instead it was merely the forerunner of thousands of distant, similar objects in the Sun's far-flung Kuiper disk.

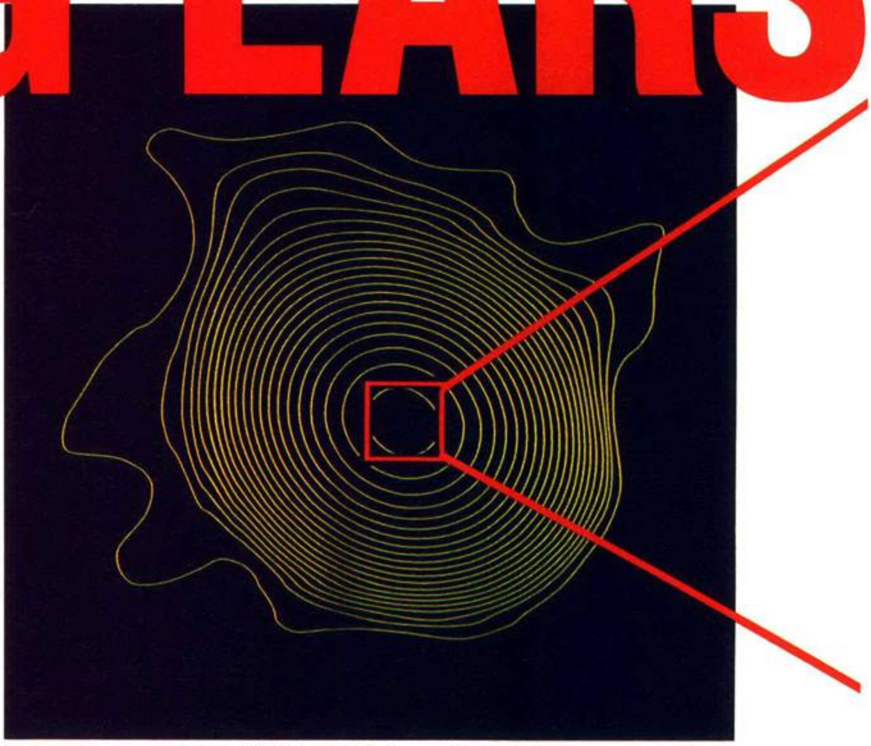
Finally, we are also discovering that our Sun resembles some other stars circled by debris disks of planetesimals — remnants of planetary formation that forever orbit in the cold vacuum beyond the distant, fully formed planets. ☐

Alan Stern is a planetary scientist at the Southwest Research Institute in San Antonio.

BIG EARS

Two new telescopes allow astronomers to "listen" for faint radio sources and to study them in greater detail than before.

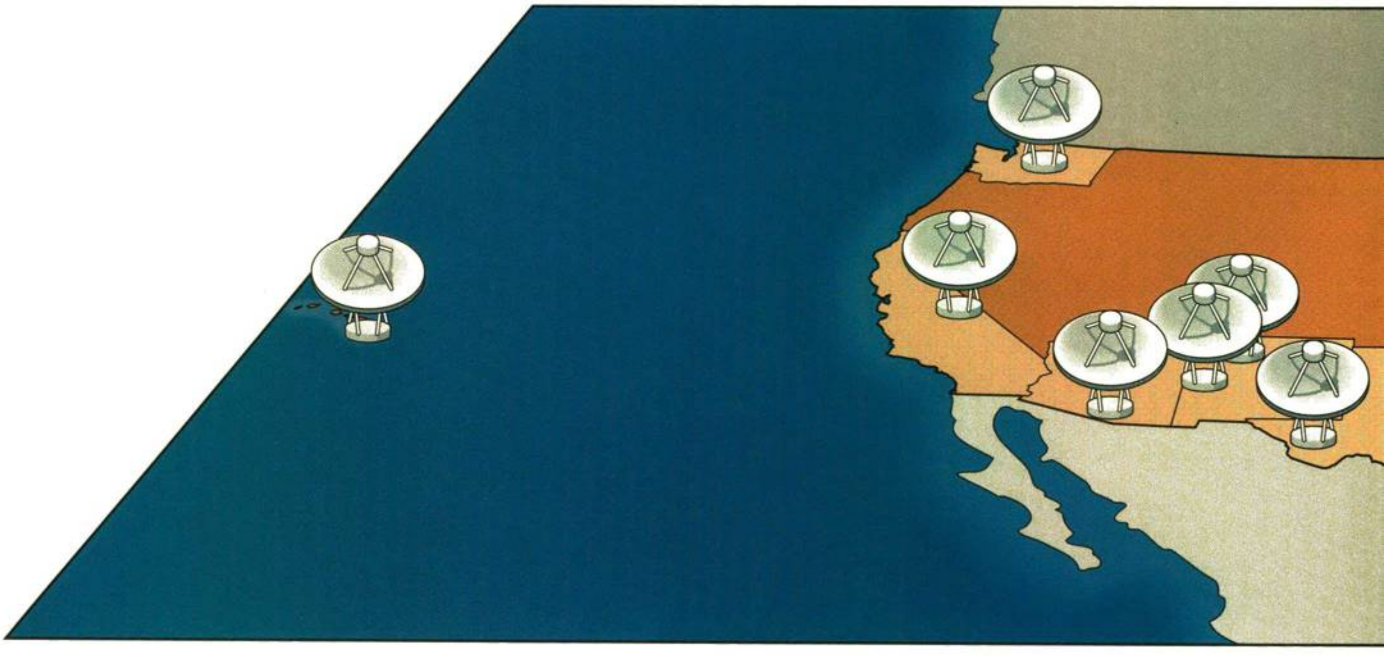
by Robert Bunge

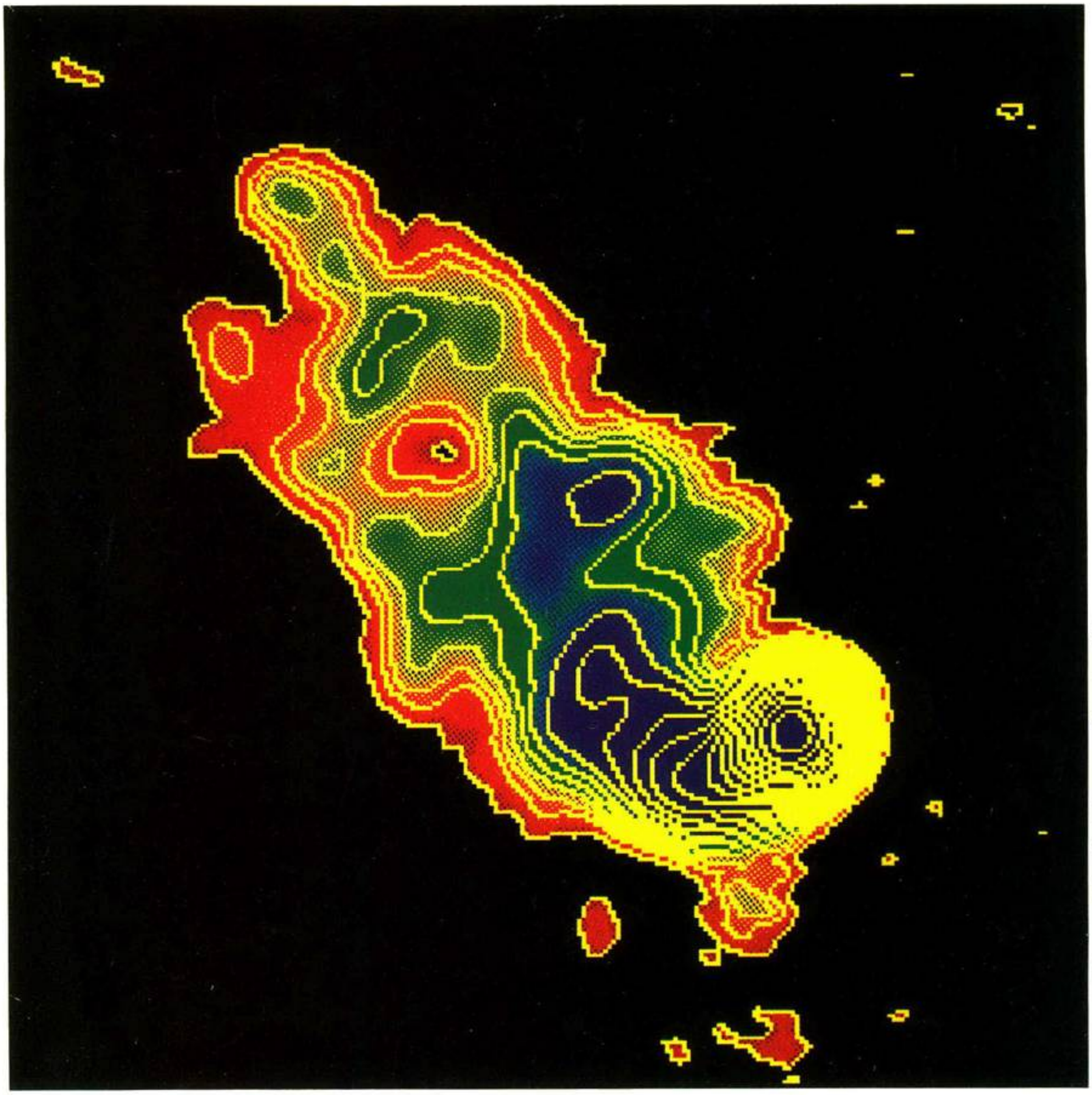


M. Wrobel and J. E. Conway, National Radio Astronomy Observatory/AUI

Just as the Keck telescope on Mauna Kea in Hawaii and other giant scopes have revolutionized optical astronomy, two new radio telescopes will open fresh vistas for radio astronomers. The first, actually a collection of 10 radio dishes called the Very-Long-Baseline Array, will enable radio astronomers to view the hearts of galaxies and quasars in unprecedented detail. The second is a single dish 2.5 acres in size called the Green Bank telescope. Its giant "ear" will let researchers listen for sources too faint to be heard by any other radio telescope.

The growth in the size (and thus the sensitivity) of radio scopes is perhaps even more dramatic than that of optical telescopes. After all, radio astronomy began in the 1930s, when Karl Jansky detected radio emissions





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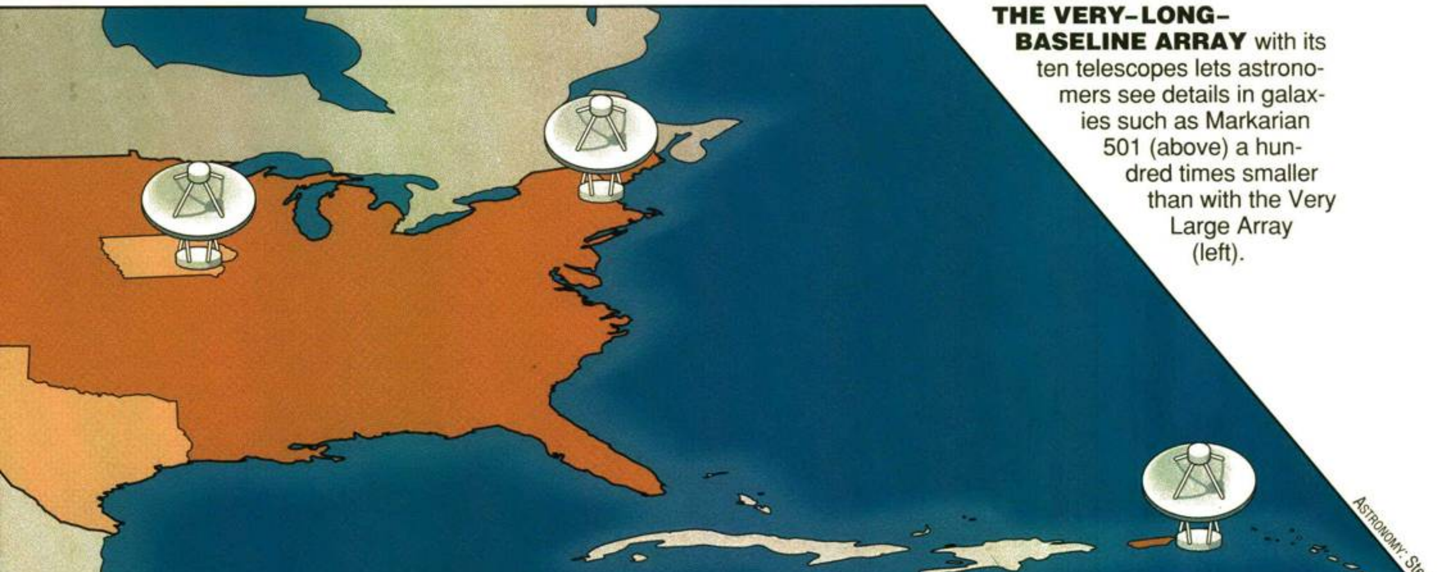
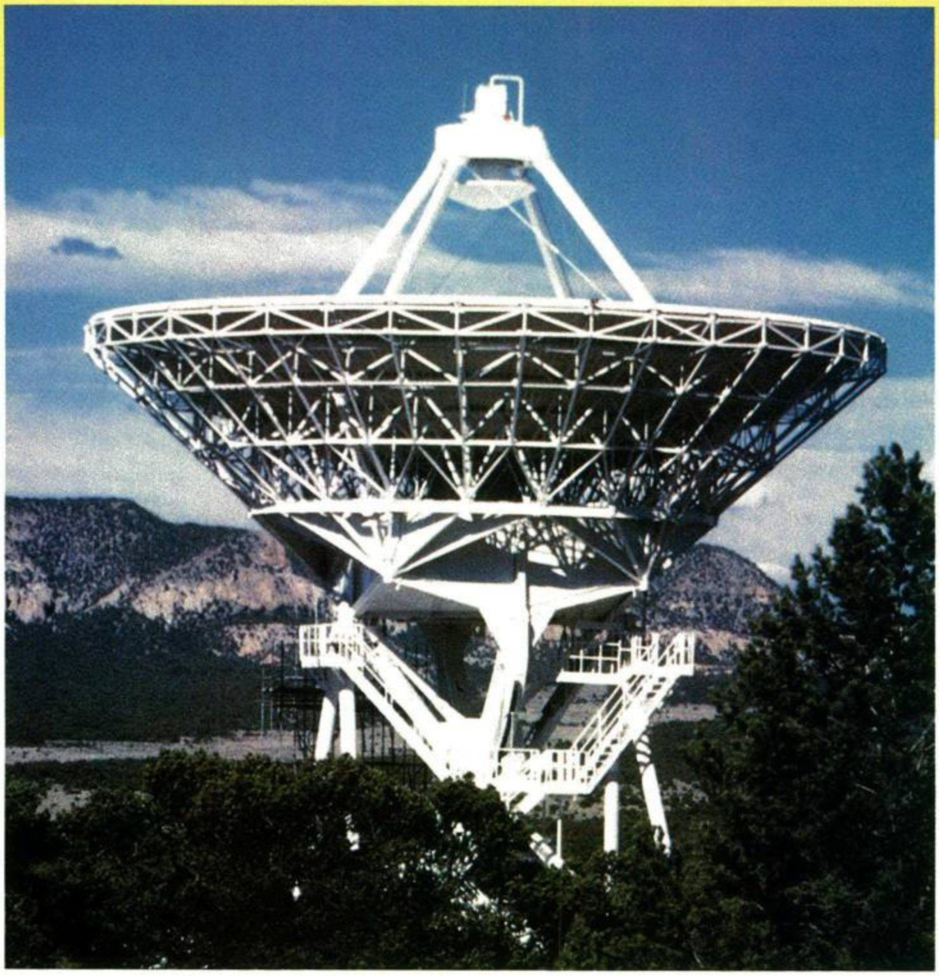


THE VERY-LONG-BASELINE ARRAY with its ten telescopes lets astronomers see details in galaxies such as Markarian 501 (above) a hundred times smaller than with the Very Large Array (left).

ASTRONOMY: Steven G. Davis

PROJECTS THAT WILL USE THE VERY-LONG-BASELINE ARRAY

Measuring the distances to galaxies
Determining the age of the universe
Studying the evolution of stars and galaxies
Investigating the energetic outbursts of quasars
Exploring the nuclei of galaxies
Measuring the motions of Earth's continental plates



STRETCHED ACROSS 5,000 MILES, the radio dishes of the Very-Long-Baseline Array spread from the Virgin Islands to Hawaii, with the heart of the array located in New Mexico.

coming from our Milky Way Galaxy. In 60 years radio astronomy has progressed from measuring only the general direction of a radio source to viewing details finer than those revealed by the Hubble Space Telescope. In comparison, it took optical astronomers 75 years to step up from the 2.5-meter diameter of the Hooker telescope at Mount Wilson Observatory in California to Keck's 10-meter diameter and achieve a much smaller increase in resolution.

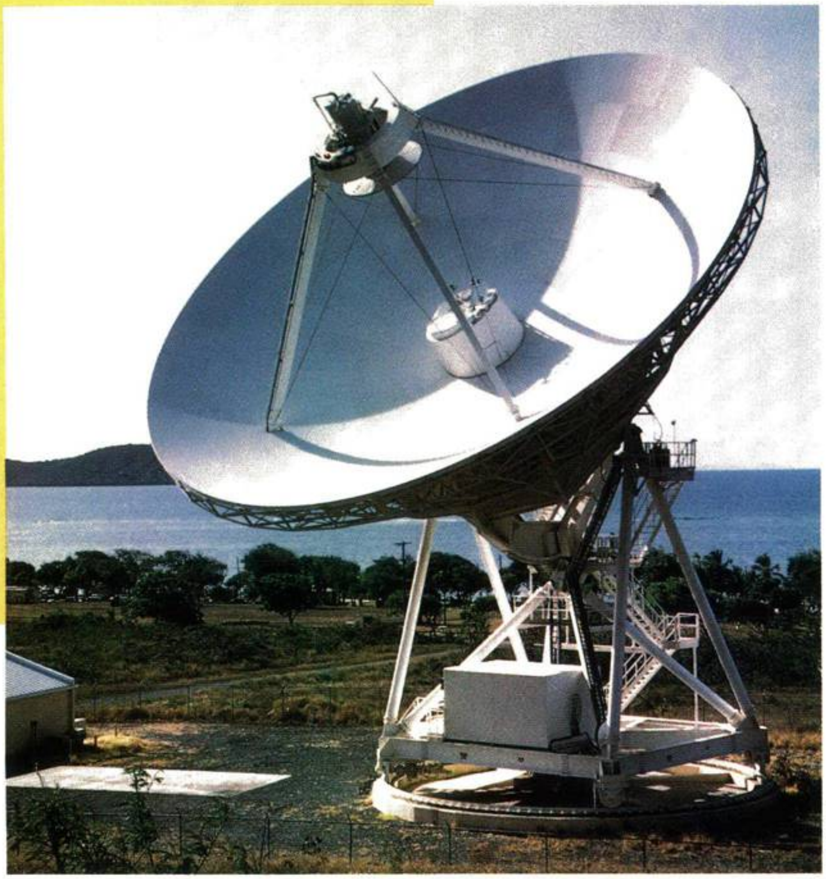
But seeing detail is just one aspect of radio astronomy. Some astronomical objects appear invisible to other kinds of telescopes, making radio telescopes the instrument of choice. Unlike the Sun, which emits most of its energy in the visible part of the spectrum, some objects emit very little in the visible but large amounts of energy at radio wavelengths.

All radio telescopes — actually directional radio antennas combined with a radio receiver — work by collecting energy emitted by astronomical objects at wavelengths that range from just a few millimeters to several centimeters in length. Although clouds stop the visible waves that your eyes see and Earth's atmosphere stops ultraviolet and infrared waves, radio waves can penetrate through the atmosphere and clouds.

Blurring by Earth's atmosphere also limits the ability of optical telescopes to see detail. But the long wavelengths that make radio waves insensitive to the blurring effects of Earth's atmosphere also limit the vision of radio telescopes.

Inch for inch, the resolving power of a radio telescope is hundreds to thousands of times lower than that of an optical telescope. But over 40 years ago radio astronomers learned that they could combine the measurements made by two antennas many miles apart to achieve the same resolution as a telescope with a diameter equal to the antennas' separation. Researchers call such an array of telescopes an interferometer and the separation of the telescopes the baseline.

Interferometry requires that you know exactly when the wave reached each telescope and how far apart the telescopes are to within a fraction of a wavelength. This is easier to do with the millimeter- and centimeter-long wavelengths of radio



NRAO/AUI

IDENTICAL TELESCOPES, 85-feet in diameter, along with special tape recorders, clocks, receivers, and high-speed computers make the Very-Long-Baseline Array possible.

waves than it is with optical waves that have wavelengths a thousand times smaller. The long wavelength of radio waves allows radio astronomers to use interferometers that have telescopes separated by large distances and, thus, to resolve objects to levels that optical astronomers can only dream of.

One powerful radio interferometer is the Very Large Array outside Socorro, New Mexico. Astronomers can move the 27 antennas of the array along Y-shaped arms up to 11 miles away from the center of the array. High-speed computers combine the signals from the individual telescopes to produce images with the resolution of up to a 22-mile-diameter telescope. This large effective aperture allows researchers to see details less than 0.1" across, about equal to the best ground-based optical telescopes.

The success of radio interferometers such as the Very Large Array encouraged astronomers to try even larger antenna separations. Although from time to time they combined signals from ad hoc collections of radio telescopes spread across the globe, researchers lacked a matched set of antennas and radio receivers that would make very-long-baseline interferometry feasible on a regular basis. A problem with these early attempts was that the researchers often had to carry to the radio telescopes the specialized tape recorders and clocks needed to make interferometric measurements. And it was often difficult to schedule simultaneous observations on the different telescopes because the scopes were used for many separate observing programs.

To make the most of long-baseline interferometry, astronomers decided to build a set of ten identical radio telescopes and equip them with the special tape recorders and clocks needed. They would use this radio telescope array solely for very-long-baseline interferometry. In the utilitarian terminology of scientists, the system of telescopes became known as the Very-Long-Baseline Array.

The ten stations of the Very-Long-Baseline Array spread over 5,000 miles from St. Croix in the U. S. Virgin Islands to Mauna Kea on the island of Hawaii. The other stations are at Hancock, New Hampshire; North Liberty, Iowa; Fort Davis, Texas; Los Alamos, New Mexico; Pie Town, New Mexico; Kitt Peak, Arizona; Brewster, Washington; and Owens Valley, California.

The Pie Town antenna was the first one built and the Mauna Kea antenna the last. Construction of the array started in 1986 and finished in April 1993. Although the formal dedication of the array occurred in August 1993, astronomers started to use parts of the array in 1987.

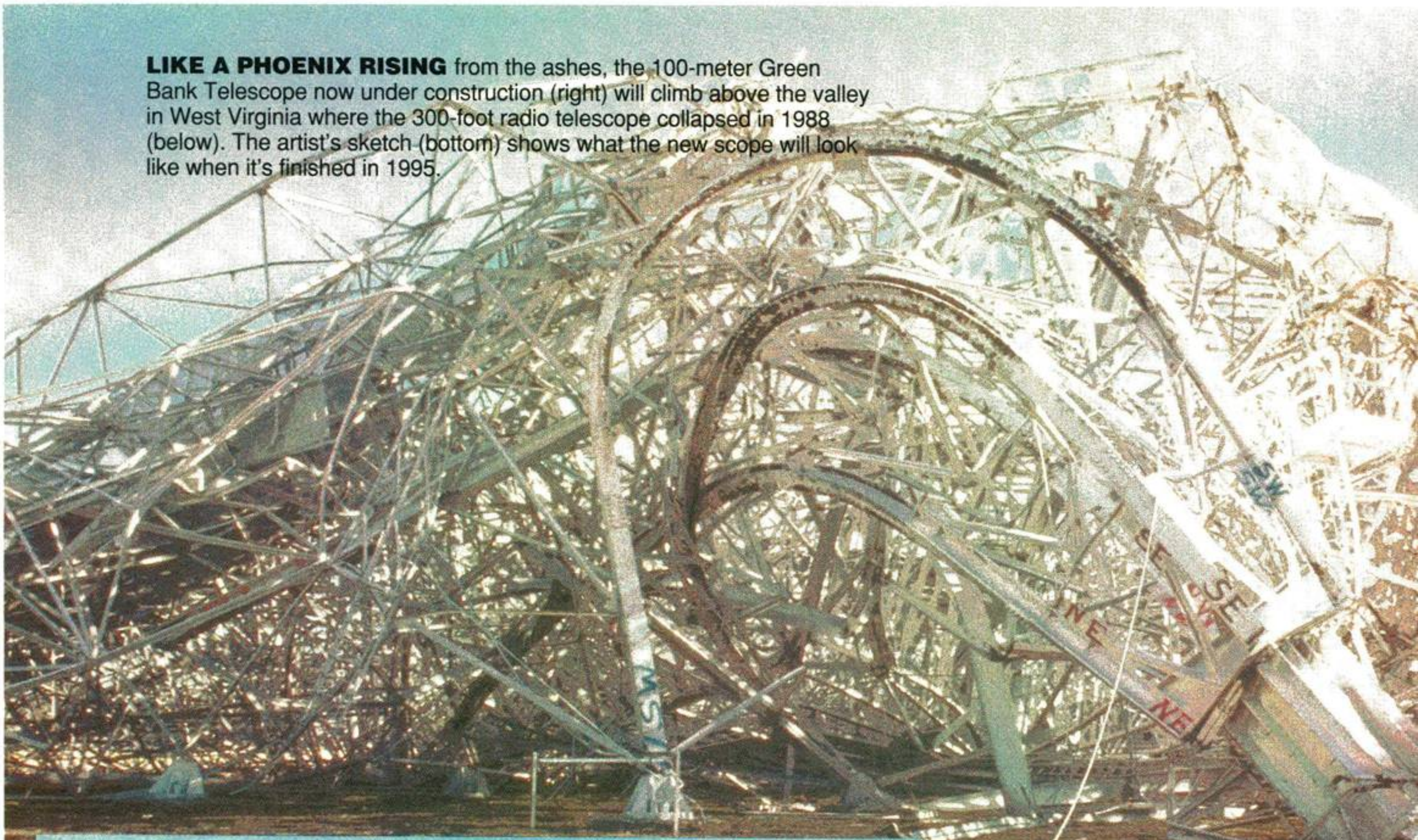
Each antenna in the array individually records the celestial signals it receives. Atomic clocks time the arrival of each signal at the telescope. These times are accurate to one second in a million years (one in over 30 trillion seconds). Observers then send the tapes from each telescope to the array operations center in Socorro. Special high-speed computers that can perform 750 billion multiplications every second read the tapes, combine the signals from the antennas in the array, and produce an image of the object.

Using the full array, astronomers achieve a resolution of around 0.0002", which is over two hundred times better than that of the Very Large Array. This resolution is equivalent to reading the print in a New York newspaper from Los Angeles.

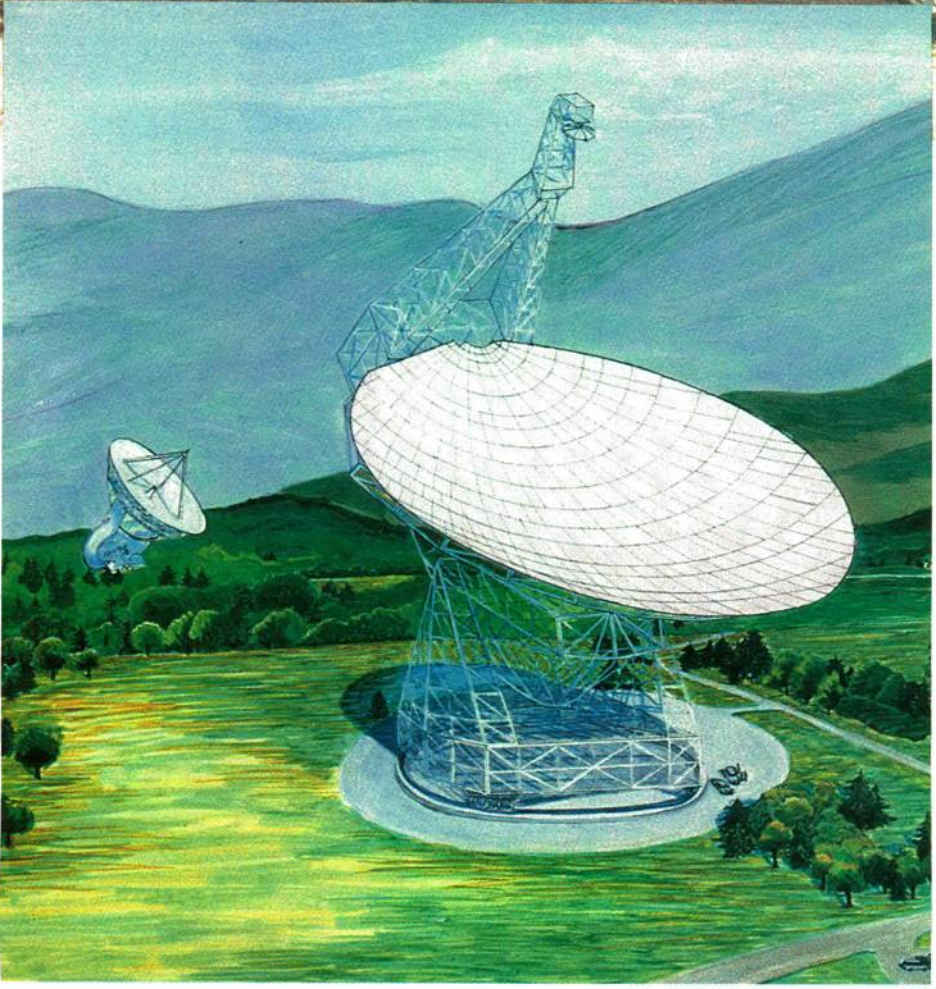
"The Very-Long-Baseline Array will allow us to observe detail in the cores of quasars," says Anton Zensus, a scientist with the National Radio Astronomy Observatory. "Early studies with radio telescopes showed that some of these objects have jets of matter that appear to be moving faster than the speed of light." These jets erupt from the core of the quasar and indicate that the core contains a powerful source of energy. The jets will also undergo the scrutiny of Zensus and other astronomers as they probe quasars with the array.

D. C. Backer of the University of California at Berkeley and his coworkers have recently used five antennas of the Very-Long-Baseline Array to look at the radio source called Sagittarius A* at the center of our Galaxy. Most astronomers believe this radio emission comes from gas that is being swallowed by a supermassive black hole. Their observations indicate that Sagittarius A* is less than 0.0004" across, which corresponds to a diameter less than twice that of Earth's orbit.

The Very-Long-Baseline Array will also help scientists to better understand Earth. In order to reconstruct



LIKE A PHOENIX RISING from the ashes, the 100-meter Green Bank Telescope now under construction (right) will climb above the valley in West Virginia where the 300-foot radio telescope collapsed in 1988 (below). The artist's sketch (bottom) shows what the new scope will look like when it's finished in 1995.

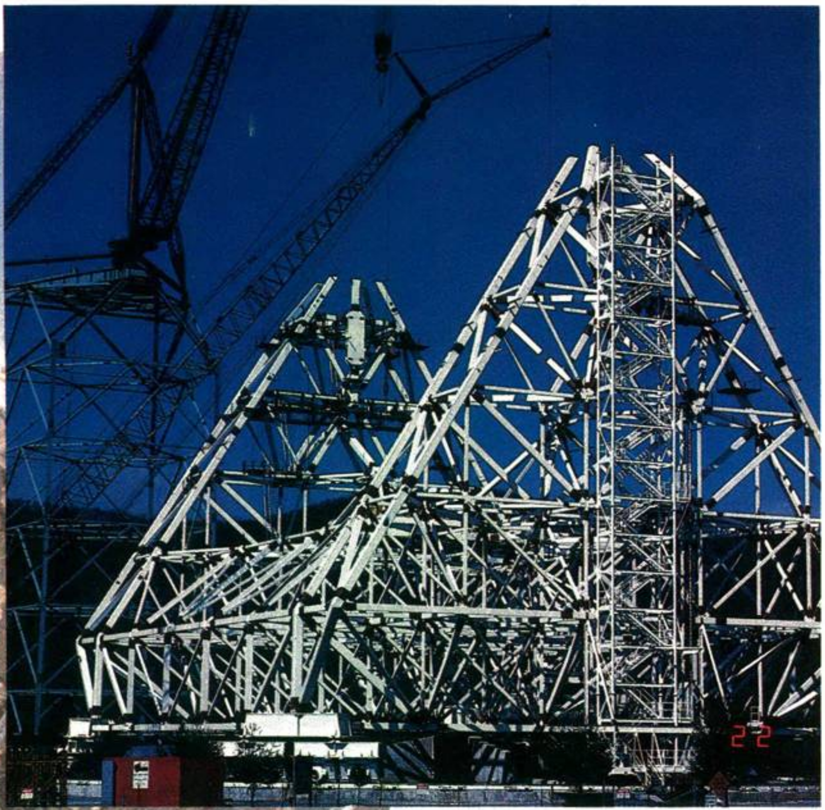


All images this page: NRAO/AUI

detailed images of celestial objects, astronomers have to know the location of each of the ten antennas down to a few millimeters. But the continents slowly drift around the globe and the crust of Earth responds to the grasp of the Moon just as the seas do. By tracking these motions, astronomers will provide a wealth of data to their earth-science colleagues for their studies of Earth's crust and earthquakes.

Observing with a telescope made up of ten different antennas stretched across 5,000 miles is difficult and tedious. For observations not requiring the high resolution of the Very-Long-Baseline Array, a single highly sensitive antenna can be better. And a large antenna is better than smaller ones for observing over a broad range of wavelengths. This is especially important for studying the low frequency (long wavelength) signals emitted by pulsars, the rapidly spinning cores of collapsed stars.

Nestled in the rolling green



mountains of West Virginia is the Green Bank site of the National Radio Astronomy Observatory. Here a giant antenna called the Green Bank Telescope is taking the place of a fallen comrade.

For more than 20 years, radio astronomers at Green Bank used a radio telescope with a dish 300 feet across. But in November 1988 a metal plate in the telescope failed and the 300-foot telescope collapsed into a jumbled mass of twisted metal. Astronomers lost one of their important workhorses.

Less than a year later the National Radio Astronomy Observatory proposed to Congress a replacement for the 300-foot telescope. According to Felix Lockwood, director of the observatory, the idea for the Green Bank Telescope was around long before the collapse of the 300 foot. "Naturally, radio astronomers had often discussed ideas of what a next-generation telescope would be like and what we'd like it to be able to do." As tragic as the collapse was, it opened the door for the Green Bank Telescope. Congress approved the new telescope in October 1989 and construction started in May 1991.

The first thing one notices when looking at a drawing of the telescope is that it doesn't look quite like a traditional radio telescope. Instead of four supports holding the receiver at the focus of the dish, the telescope uses a single support off to one side to hold the receiver where it doesn't prevent radio waves from hitting the dish.

"This design cuts down on the noise," says Lockwood. Because radio waves tend to reflect off metal objects, radio signals generated by humans often bounce off the supports of radio telescopes into the dish and up to the receiver. But the Green Bank Telescope's single support can't reflect waves into the dish and back into the receiver. This means that the receiver won't pick up as much static and will hear faint signals from the universe more clearly.

When the Green Bank Telescope is finished in late 1995, it will have a diameter of over 320 feet and be the largest fully steerable radio telescope in the world. More than 2,100 solid panels will focus radio waves on a receiver that when pointed straight up to the zenith is taller than the Statue of Liberty. The solid panels allow astronomers to receive a larger range of wavelengths than they could with mesh panels as found in some other giant radio dishes. To help manage this huge telescope, computers and lasers will monitor the distance between each of the panels and the receiver, and motors will reposition any errant panels to maintain the dish's shape to a tenth of a millimeter. More lasers on the ground will help observers point it to within a few seconds of arc.

"There aren't any other active-surface radio telescopes," says Lockwood. "The Green Bank Telescope will be limited not by the accuracy of the surface of the dish but by how well we can point the telescope as it tracks celestial objects." Lockwood explains that the pointing is difficult not only because the pull of gravity changes the telescope's shape as it tracks an object across the sky, but also because winds will warp the dish's shape and cause the telescope to shake and vibrate.

By April 1994, workers completed the rotating base of the telescope and the towers that permit the telescope to move up and down (the mount is an altazimuth, much like the head of a camera tripod). Engineers expect that it will take only another year to finish the mount, build the disk, install the reflecting panels, and erect the receiver tower. "We should start observing sometime in 1995," Lockwood says. Astronomers plan to start collecting data even as engineers fine-tune the shape of the dish.

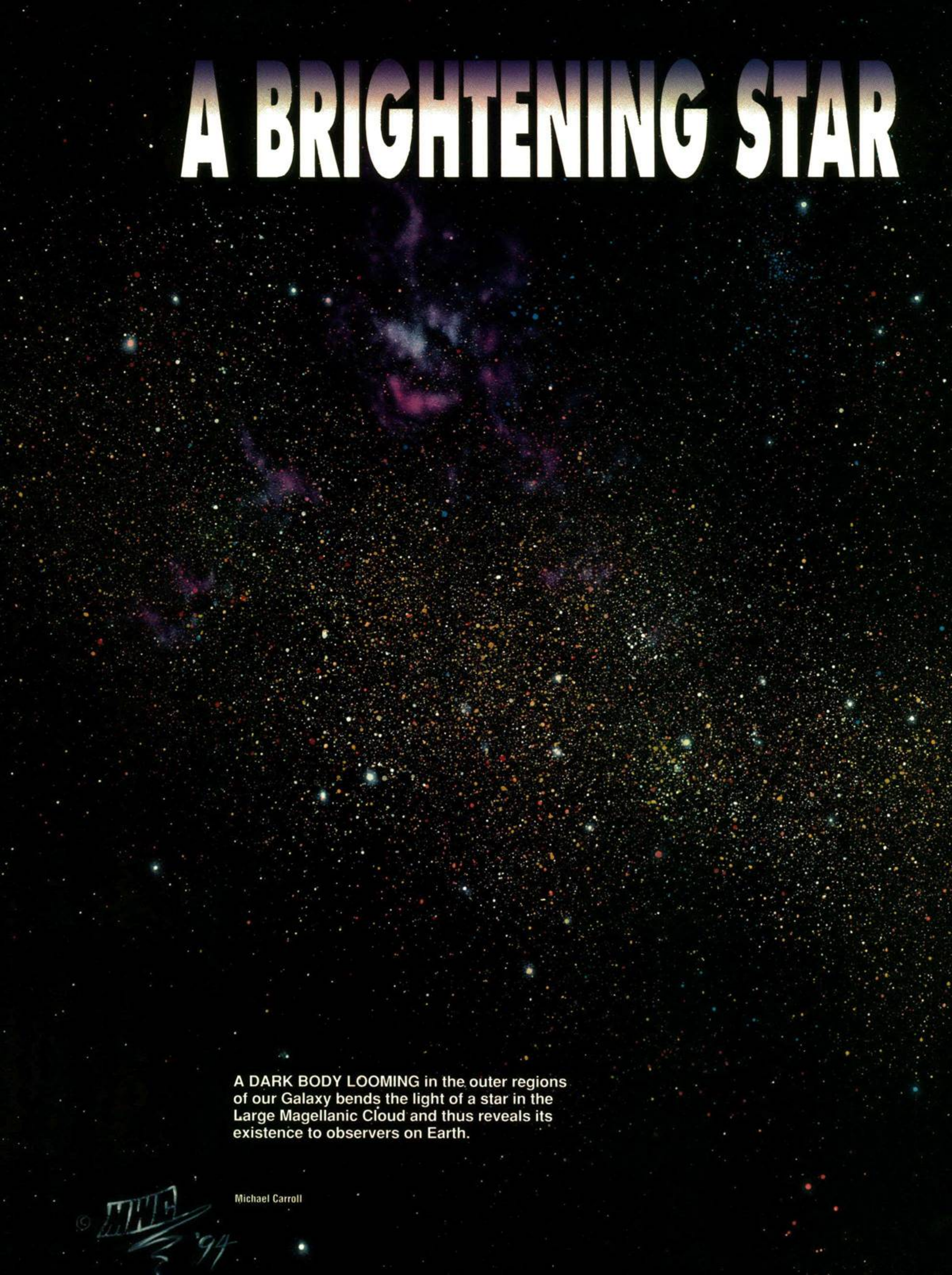
The clear signals collected by the Green Bank Telescope will allow astronomers to better study objects like pulsars, molecules that occupy the spaces between the stars of our Galaxy, and the distribution of hydrogen in distant galaxies. They will also survey radio sources too faint to have been picked up by smaller antennas.

The telescope will also combine its power with that of the Very-Long-Baseline Array. By using the Green Bank Telescope in the array, astronomers will more than double the collecting area of the array and the sensitivity of the ten telescopes to faint objects.

The continued development of new technology is fueling the growth of radio astronomy — it is assuming a pivotal role in astronomy today. The big ears of the Very-Long-Baseline Array and the Green Bank Telescope will listen for fainter, more distant objects with greater clarity than ever before. ☐

Robert Bunge writes frequently for ASTRONOMY. *His last feature was "Big Scopes: Dawn of a New Era" (August 1993).*

A BRIGHTENING STAR



A DARK BODY LOOMING in the outer regions of our Galaxy bends the light of a star in the Large Magellanic Cloud and thus reveals its existence to observers on Earth.

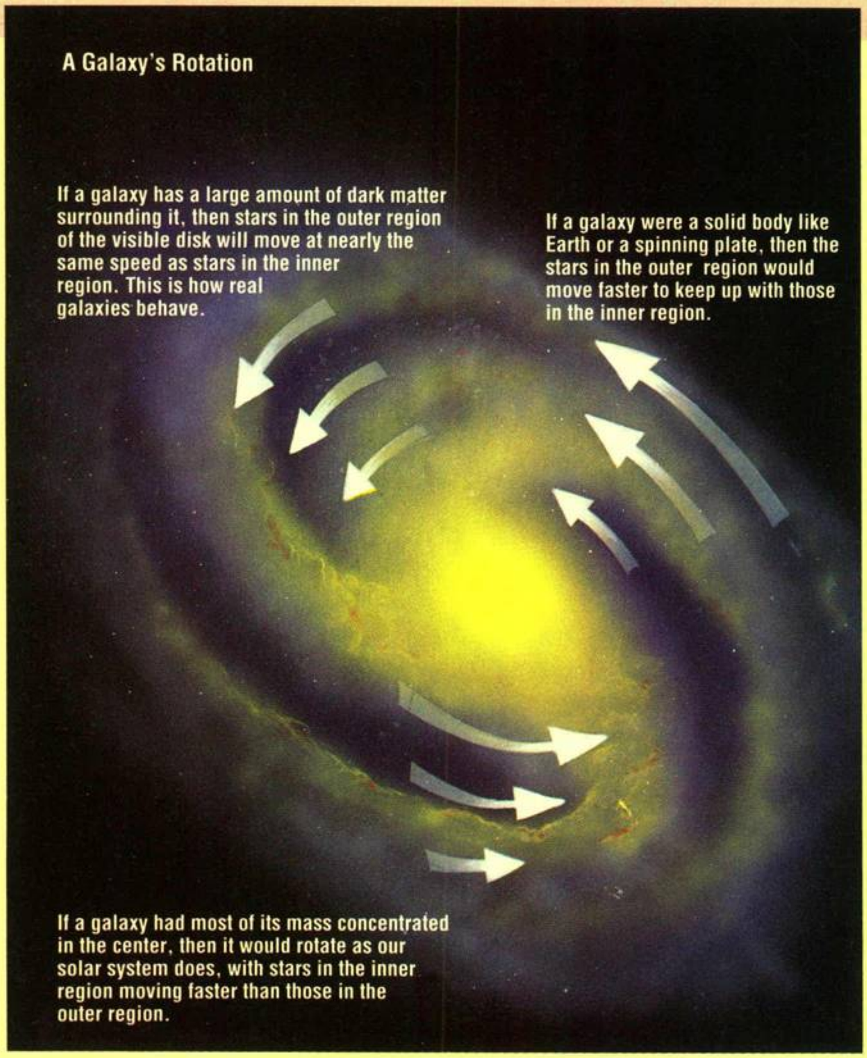
Michael Carroll

REVEALS DARK MATTER

Astronomers have long known that 90 percent of our universe is dark matter. But only recently have they caught a glimpse of it, by watching a star brighten in the Large Magellanic Cloud.

by Wallace Tucker

EVIDENCE FOR DARK MATTER

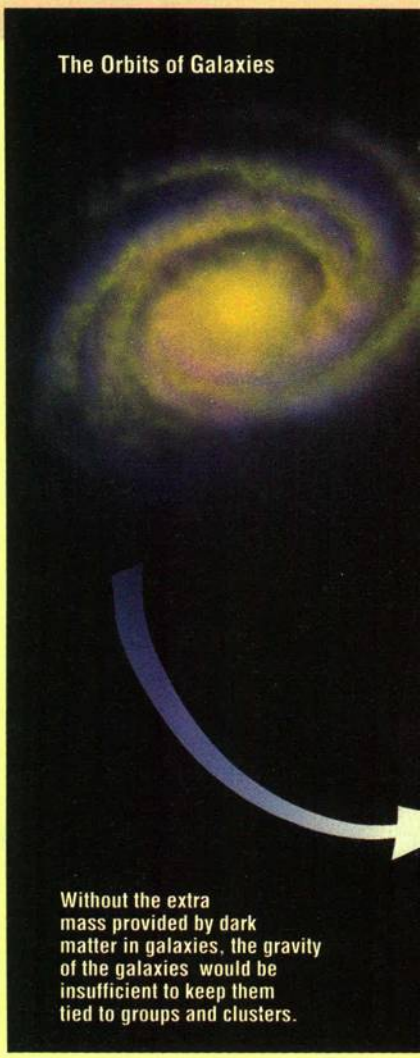


A Galaxy's Rotation

If a galaxy has a large amount of dark matter surrounding it, then stars in the outer region of the visible disk will move at nearly the same speed as stars in the inner region. This is how real galaxies behave.

If a galaxy were a solid body like Earth or a spinning plate, then the stars in the outer region would move faster to keep up with those in the inner region.

If a galaxy had most of its mass concentrated in the center, then it would rotate as our solar system does, with stars in the inner region moving faster than those in the outer region.



The Orbits of Galaxies

Without the extra mass provided by dark matter in galaxies, the gravity of the galaxies would be insufficient to keep them tied to groups and clusters.

Despite making up 90 percent of the mass of the universe, dark matter has puzzled astronomers. They can't see it, and thus identify it because it gives off no light. But a recent breakthrough may indicate just what form this matter takes. During the last couple of years, astronomers have looked at the Large Magellanic Cloud, a companion galaxy to our Galaxy, and found that a star slowly brightened and then faded again.

"It could be a new type of variable star," says Kim Griest, a physicist at the University of California at San Diego, "or it could be microlensing." Microlensing is the gravitational focusing of a star's light by a large planet or another star. Such an invisible star or Jupiter-sized object and trillions of other bodies just like it might make up our Galaxy's dark matter.

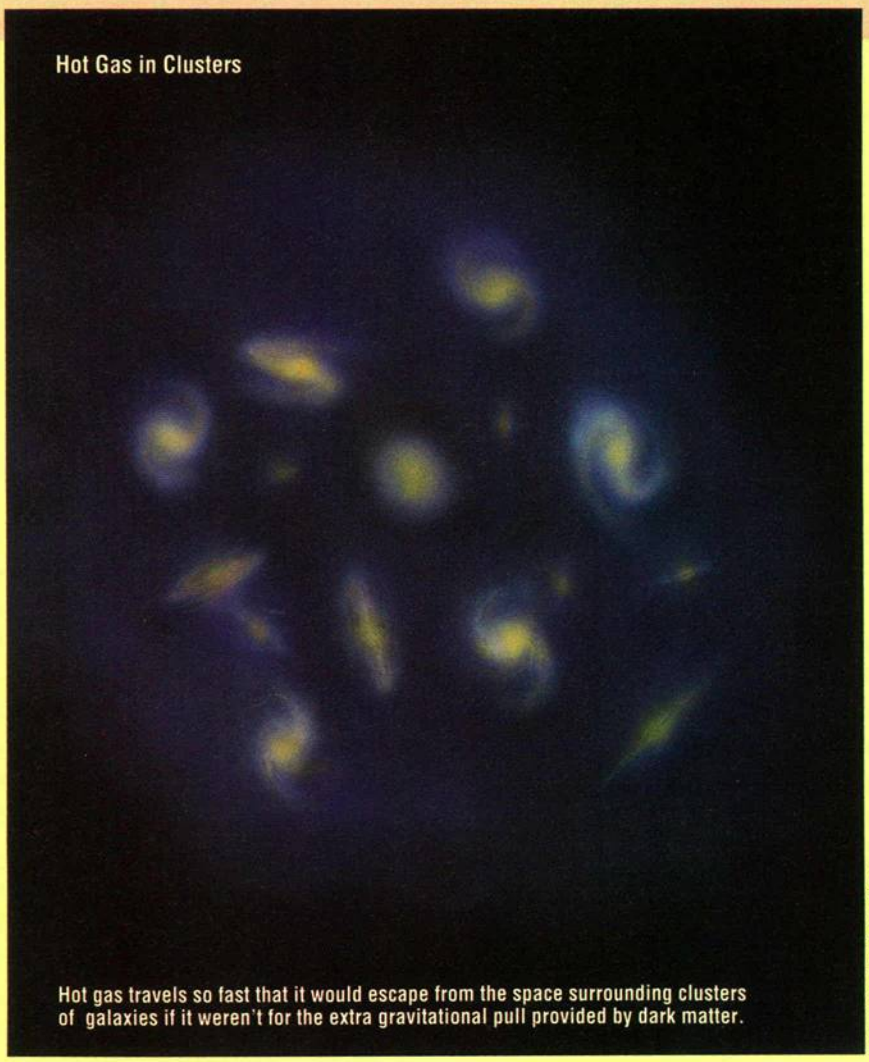
The microlensing event is the first direct evidence of dark matter. Previous evidence accumulated during the last two decades came from three sets of indirect observations: the rotation of spiral galaxies, the motions of galaxies, and the presence of hot gases in clusters of galaxies. (See the illustrations above.)

Spirals rotate rapidly in their outer regions, so astronomers conclude that these galaxies require the gravitational pull of dark matter to hold them together. As an example, consider our Galaxy. Its stars form a system that has roughly the shape of a Frisbee. They don't link rigidly together so they don't rotate as a solid body like a Frisbee. Instead the stars form a system because of their mutual gravity, as our solar system does. Observations of stars in the outer reaches of our Galaxy, though, indicate that they move as rapidly as stars in the inner regions, unlike the planets that move quickly near the Sun and slowly far from the Sun. The visible stars should have escaped eons ago if they alone provided the Galaxy's gravity. So the additional gravity provided by a huge envelope of dark matter — roughly nine times as much as the luminous matter — must confine the stars.

The second line of indirect evidence also comes from galaxies. Galaxies in clusters swarm around each other at speeds that are incomprehensible unless the gravity of dark matter is holding the clusters together.

The last line of evidence involves hot gas trapped in regions of space, such as in clusters of galaxies. This fast-moving gas should have escaped from the clusters were it not for the gravity of *dark matter.*

Accepting dark matter is one thing, but discovering its form is another. Researchers have considered black



Hot Gas in Clusters

Hot gas travels so fast that it would escape from the space surrounding clusters of galaxies if it weren't for the extra gravitational pull provided by dark matter.

ASTRONOMY: Lee Vande Visse

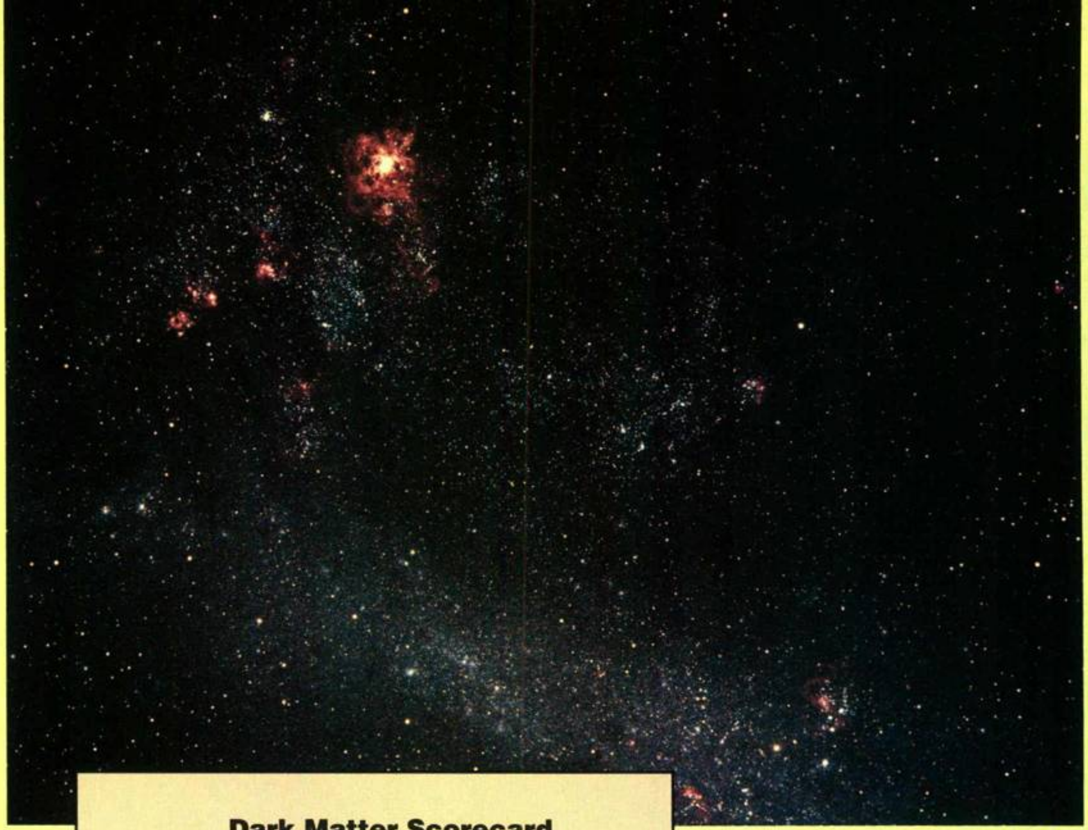
holes, brown dwarf stars, and exotic elementary particles. New instruments are searching directly for various types of particles — axions, massive neutrinos, and photinos — which represent a veritable zoo of hypothetical, weakly interacting massive particles known as WIMPs. If these instruments are successful, they could lead to a new branch of astronomy, and an extremely important one, because the detectors would be observing the primary component of the universe.

Griest and his colleagues use an indirect approach. Suppose, they reason, the dark matter in our Galaxy is in the form of dim stars in the Galaxy's outer regions or halo, which astronomers call MACHOs (MAssive Compact Halo Objects). From time to time, one of these MACHOs must get in the way of light reaching us from stars in other galaxies. This blocking will affect the starlight in a predictable and unique way.

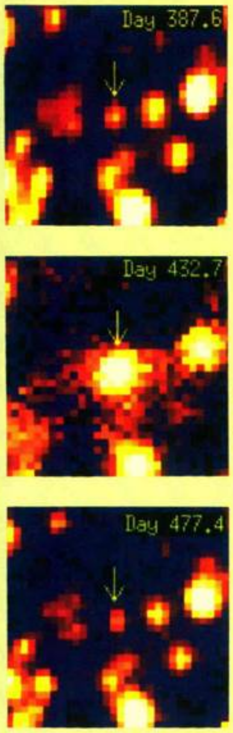
One might expect that the light from the star in the distant galaxy would get dimmer as the star in our Galaxy passes in front of it. Actually it brightens because of microlensing. (See page 45.) According to Einstein's general theory of relativity, the gravity of a star bends rays of light that pass nearby. The amount of bending depends upon the mass of the star. So a MACHO acts as a lens, with a massive MACHO intensifying the light from the distant star more than a low-mass MACHO.

The beauty of a MACHO is that it moves as it orbits the center of the Galaxy. As it moves, the alignment with the distant star changes and thus causes a short-lived brightening. The increase in the distant star's brightness will last for 10 days for a MACHO with a mass 1/100 of the Sun's and a 1,000 days for one with a mass 100 times greater than the Sun's. The rise and fall in brightness occurs symmetrically with time, and the distant star's color does not change during the brightening. These two characteristics form the signature of a microlensing event and help astronomers separate it from the changes of a variable star.

In one respect, microlensing is a less-than-ideal tool for searching for MACHOs. The alignment between a MACHO and the distant star must be precise, so brightening events are rare. Even if most of the Galaxy's dark matter is in the form of MACHOs, a million stars have to be monitored for months, on average, to detect one event. Until recently, observing millions of stars to detect MACHO microlensing was daunting. In the past few years, however, advances in star monitoring and computer technology encouraged a try by Charles



Luke Dodd



Charles Alcock, et al/ Lawrence Livermore Nat. Lab

THE LARGE MAGELLANIC CLOUD, because of its close proximity, is a perfect site for seeking stellar brightening events that reveal the presence of dark matter in the outer regions of our Galaxy.

Alcock of the Lawrence Livermore National Laboratory in Livermore, California, and 17 of his colleagues — including Griest — from six other institutions in the United States and Australia.

This so-called MACHO collaboration looks at two million stars in the Large Magellanic Cloud for five minutes every night, weather permitting. They have dedicated a 1.3-meter telescope on Mount Stromlo in Australia to the project, which started in mid-1992 and should run until mid-1996. The telescope allows simultaneous imaging of the stars in red and blue light by two charge-coupled device (CCD) cameras.

A French group of 28 scientists from six institutions has taken a similar but slightly different approach. This group, called EROS (for Expérience de Recherche d'Objets Sombres), is led by Michel Spiro of the Centre d'Études de Saclay, which is near Paris. They use digitized photographs of the Large Magellanic Cloud taken at the European Southern Observatory at La Silla, Chile.

Both groups painstakingly analyze the images for signs of microlensing. As of early 1994, Griest had traced the brightness of over a million stars. He had found many examples of well-known types of variable stars and a few promising microlensing candidates. These fell by the wayside when he compared the brightness variations in red and blue light and found them to be different, contrary to the microlensing hypothesis. By the end of February, Griest was about ready to conclude that MACHOs, if they exist at all, are too rare to contribute significantly to the dark matter. Then in early March, he found an event that met all the criteria.

The light from an undistinguished giant star in the Large Magellanic Cloud brightened over a period of al-

Dark Matter Scorecard

Astronomers have considered many possible forms for the dark matter in galaxies. Here's the status of some of these ideas.

Brown dwarfs — these objects are too low in mass to become stars. They would have to be 200 times more prevalent than red dwarf stars, but so far observers have found only one or two possible candidates for brown dwarfs, making such large numbers of brown dwarfs unlikely. The recently discovered microlensing events, however, revive interest in brown dwarfs as a form of dark matter.

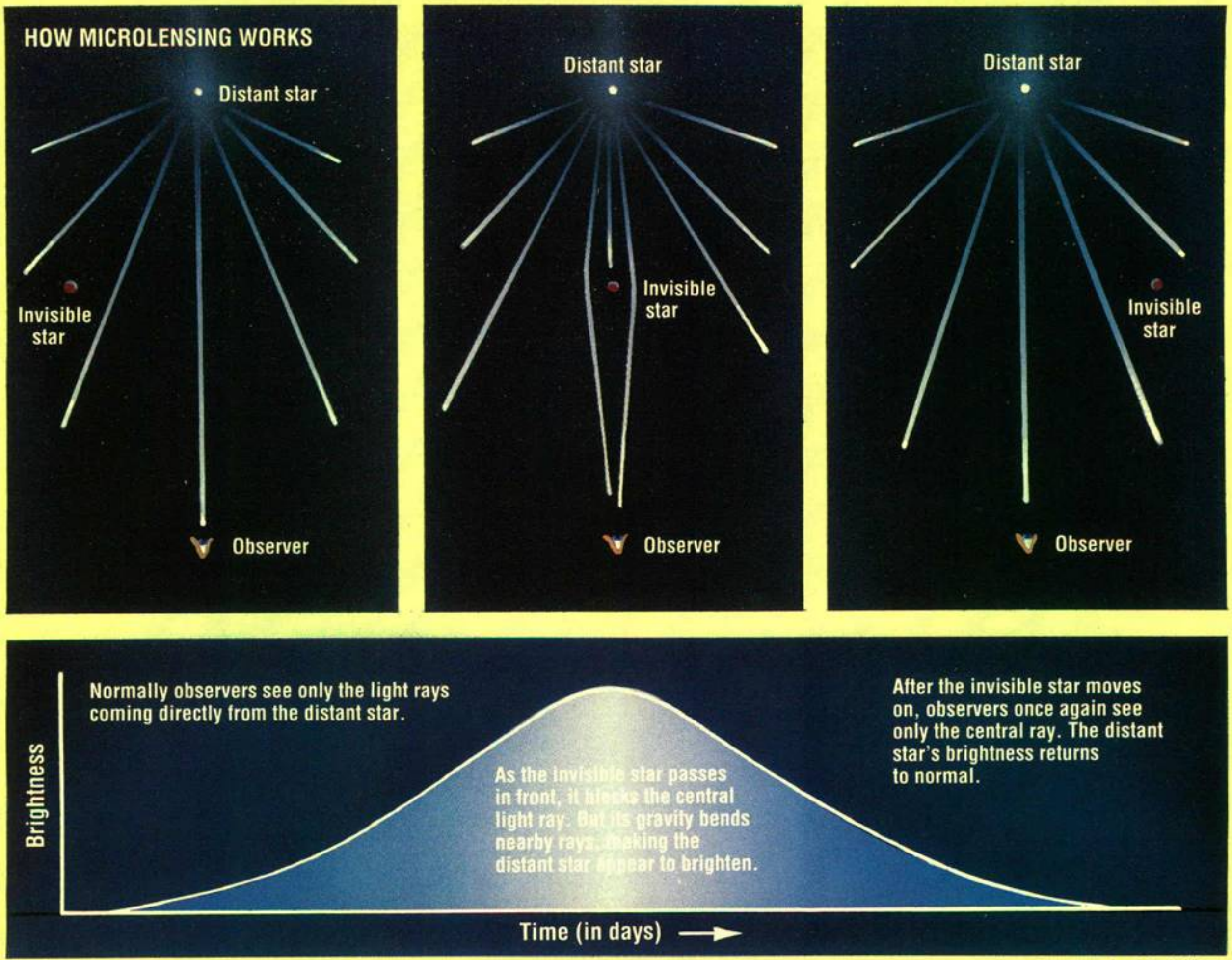
Dust — large amounts of dust would obscure light from distant galaxies more than is observed, so it can't contribute in a major way to dark matter.

Exotic particles — scores of theoretical subatomic particles exist, such as axions, massive neutrinos, and photinos. Because high-energy physicists have yet to detect these particles, they remain good candidates for the dark matter.

Hydrogen gas — emission or absorption lines would betray the presence of large amounts of hydrogen gas. Most astronomers have ruled out this possibility, although a few believe that dark matter could hide as numerous small, cold clouds of gas that never formed stars.

Stellar mass black holes or neutron stars — the stellar evolution that produces these objects would have enriched the Galaxy with much more of the heavy elements than observers detect, so they are out too.

White dwarfs — our Sun will become a white dwarf when it uses up its nuclear fuel. White dwarfs could be the dark matter if young galaxies produce enough rapidly cooling white dwarfs and can hide the helium produced by the stars during their lifetime.



HOW MICROLENSING WORKS

Normally observers see only the light rays coming directly from the distant star.

As the invisible star passes in front, it blocks the central light ray. But its gravity bends nearby rays, making the distant star appear to brighten.

After the invisible star moves on, observers once again see only the central ray. The distant star's brightness returns to normal.

ASTRONOMY: Lee Vande Visse

most 34 days and then declined over a similar interval. And the star showed no color change as it brightened. It met both criteria for a microlensing event.

"The detection by the MACHO collaboration is most convincing," observed Emilio Falco, an expert in gravitational lensing from the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts. The French group and a team of Polish and American astronomers headed by Bohdan Paczynski of Princeton University also discovered similar microlensing events at about the same time.

Seeing the event isn't the same thing as seeing the MACHO. Astronomers have to deduce its nature from the duration and amount of brightening. For example, the duration depends on the MACHO's mass, distance, and speed. Unfortunately, none of these quantities are known. Using theoretical models researchers can estimate the mass of the MACHO. The microlensing object found by Griest has a mass between about one-thirtieth and one-half the mass of the Sun.

The low end of this range includes brown dwarf stars, objects about twenty times the size of Jupiter. They have too little mass to generate the nuclear reactions that make a star shine and so produce little light on their own, making them good candidates for dark matter. The high end of the range consists of normal red dwarf stars that are about half the size of the Sun. These cool, dim stars emit only about one-thousandth of the light that the Sun does, making them candidates for the dark matter.

Using visible light, the prospects for observing a MACHO candidate, especially a dim brown dwarf, are bleak. But two Princeton University astrophysicists have a different idea. Ruth Daly and Gail McLaughlin recommend starting the search for brown dwarfs in the vicinity of the Sun using space-based infrared telescopes because these stars emit more strongly in the infrared than they do in the visible part of the spectrum.

If astronomers detect brown dwarfs in this region, then their next step is to observe a nearby galaxy. If brown dwarfs alone make up the galaxy's dark matter, several hundred trillion would be required to account for the unseen mass. Researchers would try to detect the infrared glow of this vast collection of brown dwarfs.

In the meantime, the three groups will continue to scan millions of stars every night for several more years, searching for other microlensing candidates to affirm that they are detecting MACHOs. But the results so far have generated considerable excitement among astronomers and have given hope that within a few years they should know whether or not MACHOs are the primary form of dark matter in the Milky Way and other galaxies. ☐

Wallace Tucker works at the University of California in San Diego and at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts. He wrote, with his wife Karen, The Dark Matter, *a non-technical account of unseen matter.*

SKY ALMANAC

August 1994

Perseids Peak Perfectly

The early morning hours of August 12 promise one of the best displays of the Perseid meteor shower in many years. With the waxing crescent Moon setting before midnight, the prime observing hours after midnight offer a dark sky to Perseid hunters. And since the Perseids' parent comet, Swift-Tuttle, returned to the inner solar system in late 1992, a strong display seems almost certain.

Venus Brightens August Evenings

Venus dominates the evening sky this month as it reaches its greatest separation from the Sun. On August 24 it appears 46° east of the Sun, placing the −4.4-magnitude planet well up in the west as darkness falls.

A Trio of Asteroids

Three asteroids grace the sky during August, including a near-Earth asteroid making its closest approach to our planet in over 200 years. A 10th-magnitude asteroid, 1620 Geographos, races out of the southern sky through Capricornus and Aquarius in late August (see page 58 for more). Asteroids 16 Psyche and 29 Amphitrite glow at 9th magnitude and reside in Capricornus, where they move in a more stately manner (see page 52).

Mars and a Messier Cluster

On the evening of August 19, Mars passes less than 1° south of the open cluster M35 in western Gemini. Binoculars will give you a good view of the ruddy, 1st-magnitude planet as it skirts the edge of this rich star cluster.

CALENDAR OF EVENTS

2 The Moon passes 3° south of Mars, midnight EDT

3 Asteroid Psyche is at opposition

7 New Moon is at 4:45 a.m. EDT

9 Pluto is stationary, 10 a.m. EDT

10 Asteroid Amphitrite is at opposition
The Moon passes 3° south of Venus, 7 p.m. EDT

12 The Moon passes 0.1° south of Spica, 3 a.m. EDT
Perseid meteor shower peaks
The Moon is at perigee (229,574 miles from Earth), 7:11 p.m. EDT
Mercury is in superior conjunction, 9 p.m. EDT

13 The Moon passes 2° south of Jupiter, 3 a.m. EDT

14 First Quarter Moon is at 1:57 a.m. EDT

18 The Moon passes 4° north of Neptune, 10 a.m. EDT
The Moon passes 5° north of Uranus, 2 p.m. EDT

21 Full Moon is at 2:47 a.m. EDT

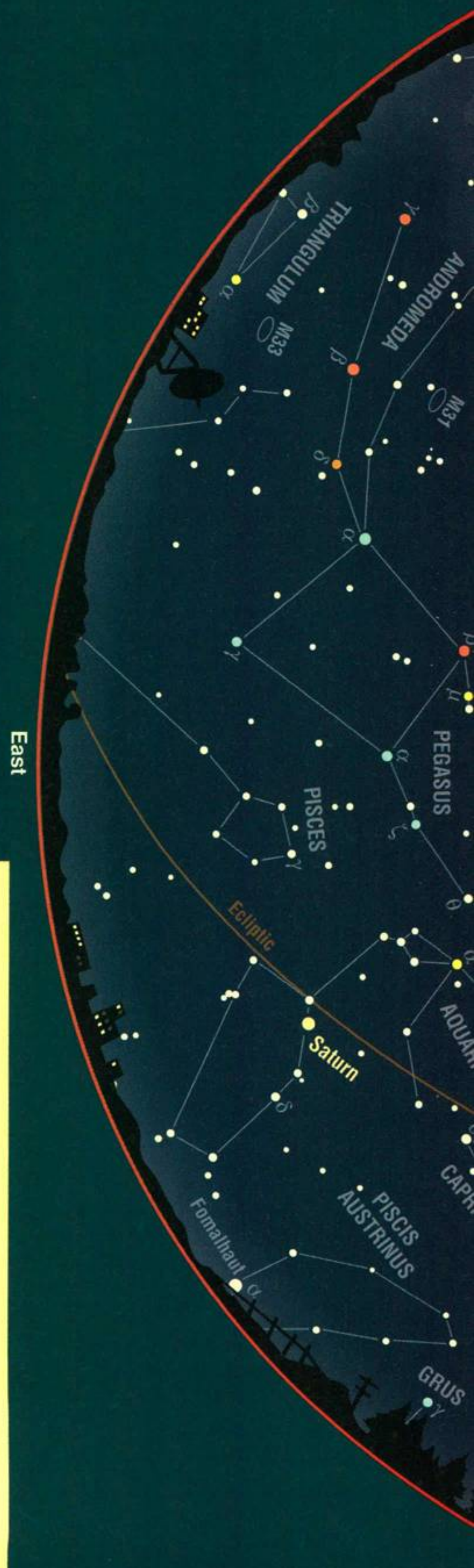
22 The Moon passes 7° north of Saturn, 6 a.m. EDT

24 Venus is at greatest eastern elongation (46°), 7 p.m. EDT

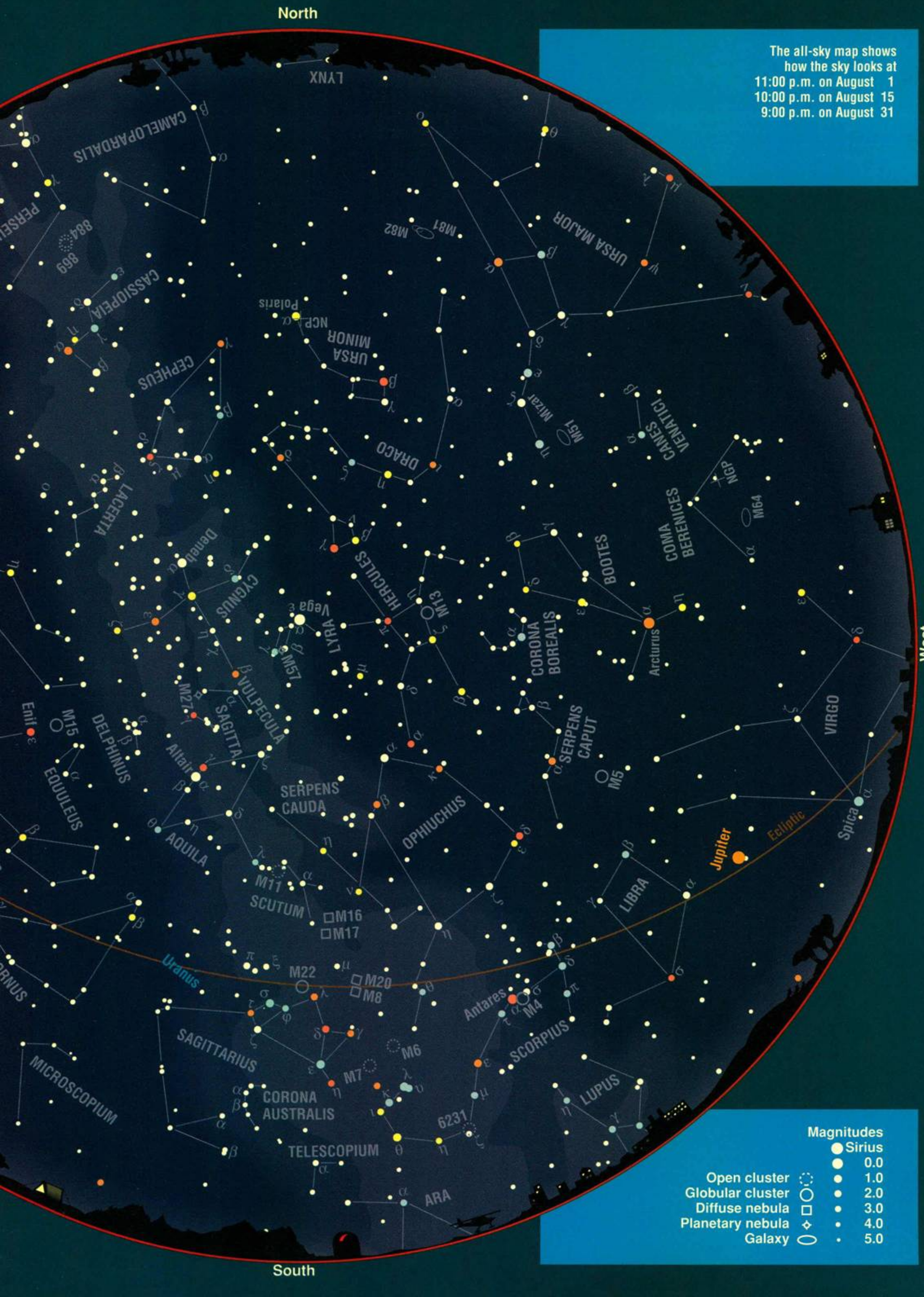
27 The Moon is at apogee (251,247 miles from Earth), 1:53 p.m. EDT
Asteroid Geographos is at its brightest

29 Last Quarter Moon is at 2:41 a.m. EDT

31 Venus passes 0.7° south of Spica, 5 p.m. EDT
The Moon passes 4° south of Mars, 11 p.m. EDT



The all-sky map shows
how the sky looks at
11:00 p.m. on August 1
10:00 p.m. on August 15
9:00 p.m. on August 31


North
LYNX
CAMELOPARDALIS
PERSEI
884
869
CASSIOPEIA
M82
M81
URSA MAJOR
Polaris
NCP
URSA MINOR
CEPHEUS
Mizar
M51
CANES VENATICI
DRACO
NGP
LACERTA
COMA BERENICES
M64
Deneb
CYGNUS
HERCULES
BOOTES
Vega
LYRA
M13
M57
CORONA BOREALIS
Arcturus
West
VULPECULA
M27
SAGITTA
Enif
M15
DELPHINUS
VIRGO
SERPENS CAPUT
Altair
M5
EQUULEUS
SERPENS CAUDA
AQUILA
OPHIUCHUS
Spica
Ecliptic
Jupiter
M11
SCUTUM
LIBRA
M16
M17
Uranus
M22
M20
M8
Antares
M4
SAGITTARIUS
SCORPIUS
M6
MICROSCOPIUM
M7
CORONA AUSTRALIS
LUPUS
6231
TELESCOPIUM
ARA
South
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

SKY ALMANAC

by Deborah Byrd and Rick Shaffer

The prospects for this year's Perseid meteor shower look excellent. With the shower peaking on the morning of August 12 and the waxing Moon setting the evening before, rural skies will be dark in the predawn hours for meteor observing. The usual rules for watching meteor showers apply. For your observing site, find an open area as far as possible from city lights. Plan to observe for at least a couple of hours after midnight. Lie on your back and carefully scan all parts of the sky. Also bring along a jacket or blanket and a thermos containing a warm drink to help keep warm.

The Perseids put on an impressive show last year in response to the return of their parent comet, Swift-Tuttle. In December 1992, the comet made its first return to the inner solar system in 130 years. That's when the excitement began building for last year's Perseid meteor shower.

Plenty of people watched that shower and appreciated its beauty. The meteors came regularly, and they made long, bright streaks across the night sky. Serious meteor observers compare their meteor counts with a standard called the "zenithal hourly rate." This rate is defined as the average number of meteors per hour that an observer would see if the meteors rained down from directly overhead in a sky where 6.5-magnitude stars can be seen with the naked eye. The zenithal hourly rate at the peak of the 1993 shower was estimated to be 350, about three times higher than usual. (A meteor "storm" might have a rate 1,000 times higher than that.)

As in some other recent years, observers occasionally saw strong bursts of meteors over brief intervals during last year's Perseid shower. Meteor watchers in Israel reported nearly one meteor every five seconds for about half an hour. There were also reports of meteoroids striking a couple of satellites in orbit around Earth. The Russian Mir space station may have been struck by Perseid

August's Dependable Perseids

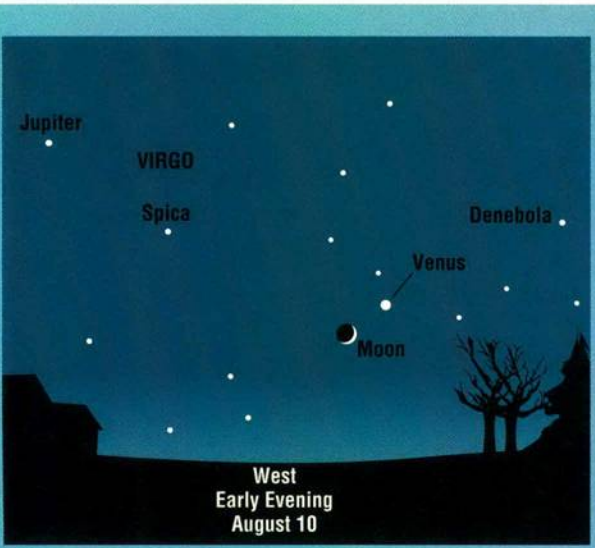
James Glenn Pearson

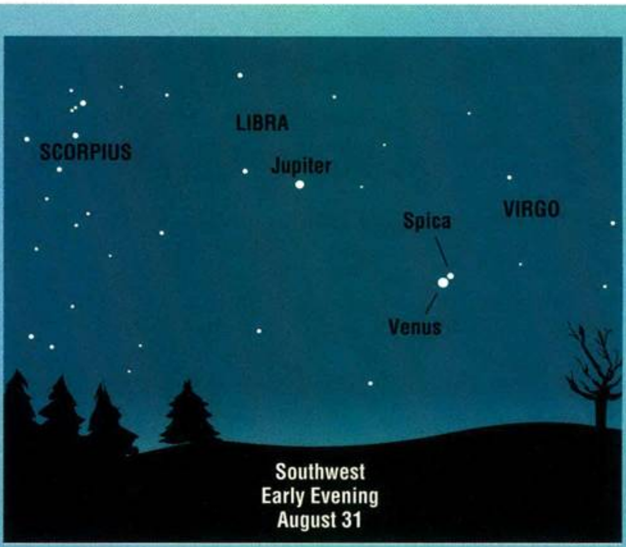
With the five-day-old Moon setting around 10 p.m. local daylight time the night before, the morning of August 12 will provide a dark sky for watching the Perseid meteor shower.

Perseid meteors originate as dusty debris spewed out by Comet Swift-Tuttle during its untold number of trips around the Sun. Each year in mid-August, Earth runs smack into this cosmic debris and our atmosphere incinerates the tiny particles, producing the flashes of light in the sky.

In most years you can expect to see 50 or 60 meteors per hour during the peak of the Perseids, but this year it's hard to know what to expect. Swift-Tuttle returned to the inner solar system in late 1992, providing a fresh supply of debris to make more meteors. Some experts predicted a meteor storm in 1993, and some areas did experience short, intense bursts of up to 700 meteors per hour. Other experts predict this is the year with the best chance of a storm, while still others predict a storm will come later in the decade. So the only way of actually seeing a meteor storm depends on being both persistent and lucky enough to be in the right place at the right time.

To enjoy the Perseids to the fullest, watch after midnight from a dark observing site that offers a clear view of most of the sky. Bring along a sleeping bag or blanket to stay warm and some bug spray to stay sane. And keep a pair of binoculars handy to examine the smoke trails that many brighter Perseids leave behind.





Venus Dominates the Evening

On August 24, Venus reaches greatest elongation at a spot 46° east of the Sun. Although this is Venus' biggest separation from the Sun for this evening appearance, the brilliant planet still lies fairly low in the western twilight sky. Geometry suggests that Venus should appear exactly half lit at this point in its orbit, but that's not the case. Most observers say half phase occurs a few days before greatest eastern elongation. Try observing or photographing Venus every day beginning around the 15th to see when half phase actually occurs.

Earlier in the month, on the evening of the 10th, Venus and the Moon provide a beautiful spectacle in the evening sky. On that date the Moon passes 3° south of Venus. This makes an excellent photo opportunity for both beginning and seasoned astrophotographers. Any lens with a focal length of 50mm or more can provide a good image of this event, especially if framed with an interesting foreground. A 400- to 600mm telephoto lens will let you capture a nice closeup image of the pair.

Finally, at the end of the month, Venus comes within 0.7° of Spica, the 1st-magnitude luminary of the constellation Virgo. The two will be low in the sky so you'll want to observe no more than about 30 minutes after the Sun sinks below the horizon.

Comet Tempel 1 on Its Way out

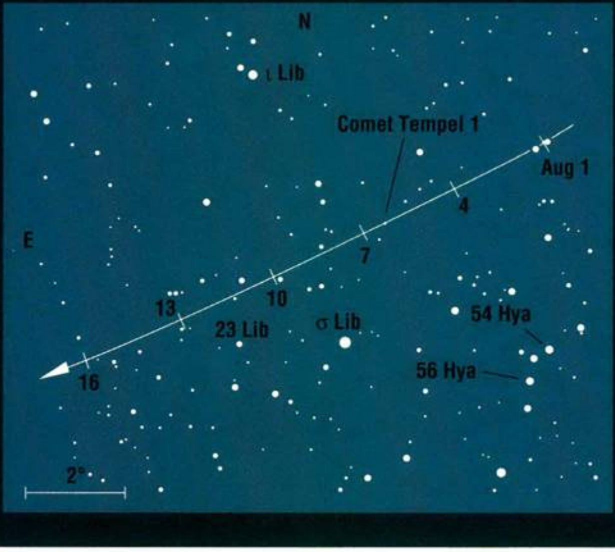
Although 1994 hasn't brought any truly bright comets, comets Encke, Tempel 1, and Borrelly glow brightly enough to be worth your attention. The best this month is Comet Tempel 1, which moves from Libra into Scorpius and dims to 10th magnitude as it recedes from both Sun and Earth.

In 1867, astronomer William Tempel discovered Comet Tempel 1, the first of two that he would discover. Fourteen years later, lucky that it did not collide with Jupiter, Tempel 1 was influenced by Jupiter's gravity, which caused its orbit to lengthen. After a string of 14 unseen apparitions, observers recovered it in 1967. This year's apparition looks like the best since then.

Under a dark sky, you can find Tempel 1 with 7x50 binoculars. However, you'll need a large telescope to see anything more than a featureless ball of fuzz, and even then you won't likely see a tail because it will be too far from the Sun for much of a tail to form.

COORDINATES FOR COMET TEMPEL 1

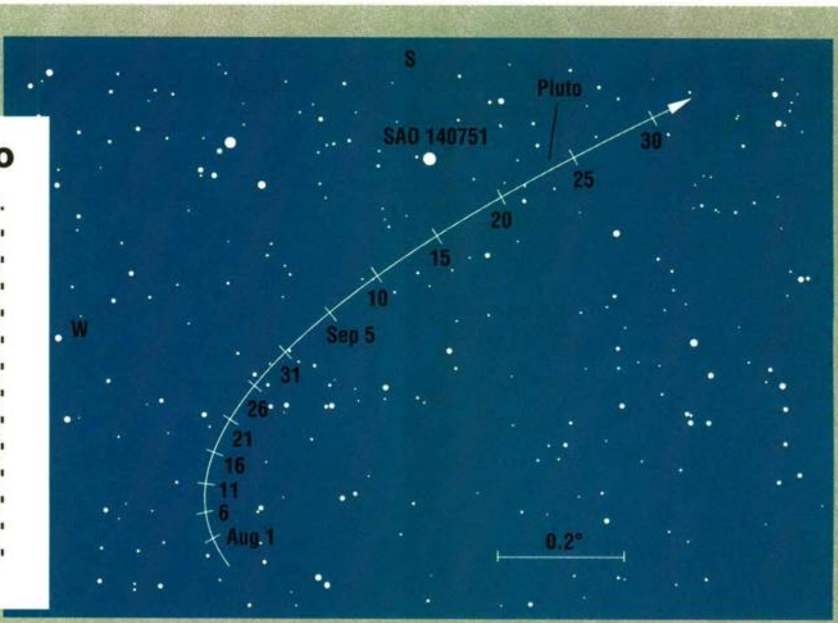
Date	R.A. (2000)	Dec.
August 1	14h46.5m	-21°11'
August 4	14h54.3m	-22°09'
August 7	15h02.3m	-23°05'
August 10	15h10.4m	-23°59'
August 13	15h18.7m	-24°50'
August 16	15h27.1m	-25°39'



Zeroing in on Pluto

COORDINATES FOR PLUTO

Date	R.A. (2000)	Dec.
August 1	15h45.4m	–5°31'
August 6	15h45.3m	–5°33'
August 11	15h45.3m	–5°36'
August 16	15h45.4m	–5°39'
August 21	15h45.5m	–5°42'
August 26	15h45.6m	–5°45'
August 31	15h45.8m	–5°49'
September 5	15h46.1m	–5°52'
September 10	15h46.4m	–5°56'
September 15	15h46.8m	–6°00'
September 20	15h47.2m	–6°03'
September 25	15h47.7m	–6°07'
September 30	15h48.2m	–6°11'

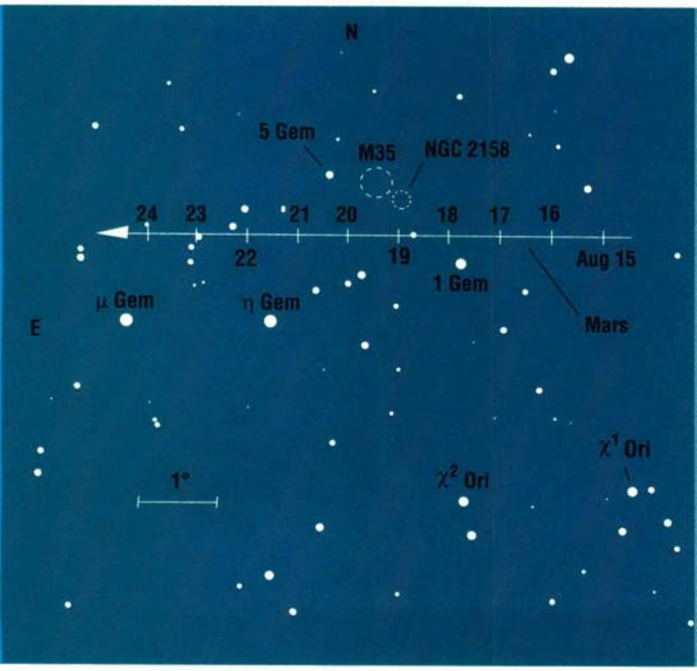


Conventional wisdom has it that finding the faintest planet, Pluto, should have been done when it reached opposition in May. And, being conventionally wise, ASTRONOMY published an article and finder chart in its May issue. However, many backyard observers don't have many clear nights or good seeing that early in the season. So it may be more practical to try to detect Pluto this month, when it is approximately 90° from the Sun in the sky.

Pluto is highest in the sky shortly after sunset, so try to look for it as soon as twilight ends. The first week of August offers the additional bonus of the Moon's being out of the evening sky. You'll need a night of good seeing and at least an 8-inch scope (though some experienced observers have detected Pluto in a 6-inch scope).

Using the chart (which shows stars to magnitude 14.5), locate the area in northern Libra where Pluto lies and then center it in the field of your lowest power eyepiece. Then increase the power until your exit pupil is no more than 2 mm. (The exit pupil is simply the aperture of the telescope in mm divided by the power of the eyepiece.) This ensures that the level of background light is below what your eyes can detect.

If you can't pinpoint Pluto from the chart alone, make a careful drawing of all the stars you see in the field. If the seeing is good, your drawing should reach past the 13.7-magnitude brightness of shy Pluto. On the next night of good seeing, repeat the process. Comparing the two drawings should reveal the one "star" that has moved. That's Pluto.



Mars and Messier's 35th Object

Viewing Mars with a telescope this month isn't particularly satisfying. It shines only at magnitude 1.2 and its disk measures only a bit over 5" in apparent diameter, too small to show much in the way of surface detail. But this month Mars provides an interesting lesson about the distances of objects in the sky.

Mars does this when it passes 0.5° south of the open cluster M35 on the evening of August 19. On that date, Mars lies 15 light-minutes away from Earth, so we are seeing Mars as it was 15 minutes ago.

However, M35 is 2,800 light-years distant from us, so we're seeing it as it was in Old Testament times. If you can find NGC 2158, a much smaller open cluster on the southwestern periphery of M35, the contrast in distances becomes even greater. NGC 2158 lies some 16,000 light-years from Earth, nearly six times farther than M35.

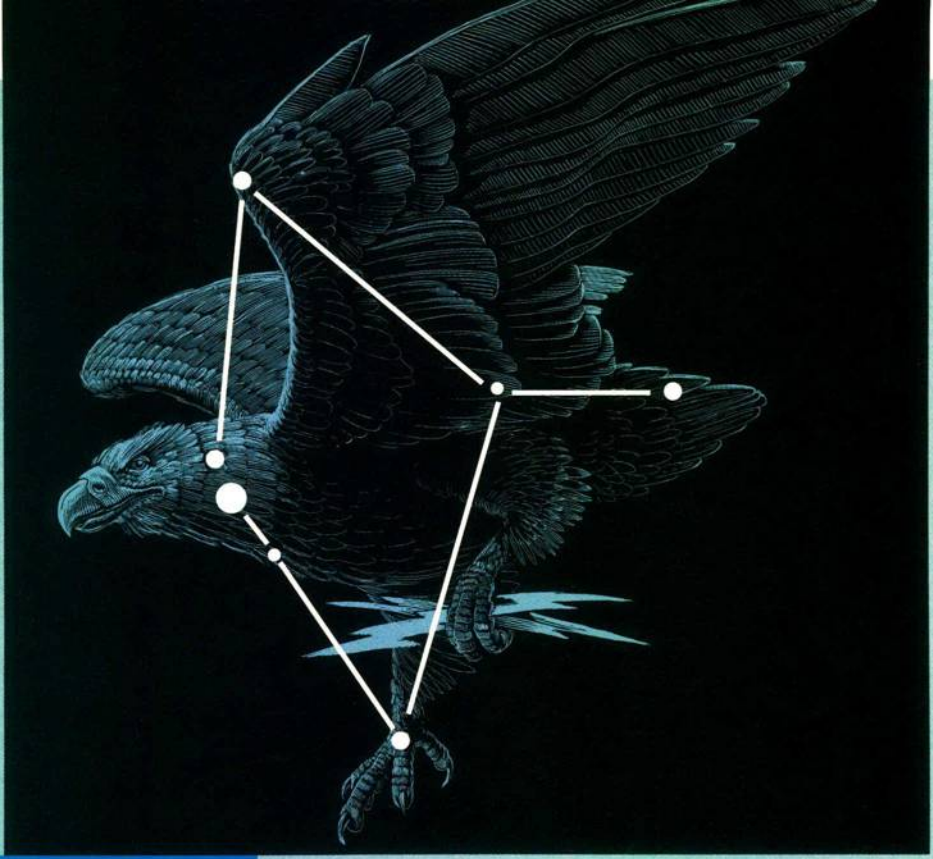
meteors as many as 60 times. And the European Space Agency's Olympus satellite began spinning uncontrollably on the night of August 11, an event some attribute to a meteoroid strike.

The big question now is whether the 1994 Perseid shower will rival that of 1993. Although no one will know for sure until August 12, many astronomers predict a similar level of activity — probably a few strong bursts but likely no major storm. So definitely plan to watch this year's shower. It should be the most exciting astronomical event since . . . well, since Comet Shoemaker-Levy 9 struck Jupiter in July. (See "A Stormy Perseid Forecast" on page 68 for more details on observing the Perseids this year.)

In the wake of all this excitement are some more ordinary but equally fascinating sky events. Venus, the brightest planet, reaches greatest elongation on August 24. It is then 46° east of the Sun — its greatest separation for this evening apparition — and is visible easily in the west after sunset. Although Venus was somewhat higher in the sky earlier this summer, it's still very prominent. It brightens perceptibly over the course of August, from magnitude –4.2 to magnitude –4.4.

Two other noteworthy events highlight Venus' activity this month. Watch on the evening of August 10 as the young Moon sweeps to within 3° of the bright planet. Then on the final day of the month, Venus passes just 0.7° south of the brightest star in Virgo, 1st-magnitude Spica.

The retrograde, or westward, motion of the planet Pluto ends on August 9. That's a signal that the best time of year to observe Pluto will soon be behind us. So now is the time to get your last views of Pluto in 1994. The distant planet glows at magnitude 13.7, making it about a thousand times too faint to be seen with the naked eye. But an 8-inch telescope and our finder chart will help you spot it. When observing it, remem-



Keith Ward

THE STARRY SKY

by Deborah Byrd

The asterism known as the Summer Triangle crosses the meridian on August evenings. This large star pattern is made up of three 1st-magnitude stars — Vega in the constellation Lyra the Harp, Deneb in the constellation Cygnus the Swan, and Altair in the constellation Aquila the Eagle. (See the June and July Starry Sky sections for more on Lyra and Cygnus.)

Altair is the brightest star in Aquila, shining at magnitude 0.8 from a distance of 16 light-years, which makes the constellation easy to recognize. This is an ordinary main-sequence star, about 1.6 times as large as our Sun and about 11 times brighter.

One outstanding feature of Altair is the speed with which it spins on its axis. Analyses of its spectrum reveal that it completes a turn in only 6½ hours, in contrast to more than 25 days for our Sun. The planet Jupiter also rotates rapidly, once in only about 10 hours. That causes the planet to appear flattened in a telescope: The planet's diameter is greater when measured across the Jovian equator than from pole to pole. Because it spins even faster than Jupiter, Altair also must be extremely flattened. Astronomers estimate its equatorial diameter is nearly twice its polar diameter.

Aquila contains its own little asterism, a row of three stars formed by Altair and two fainter companions on either side — Tarazed and Alshain, also known as Gamma and Beta Aquilae. This threesome is sometimes called the Family of Aquila.

South of Altair is 4th-magnitude Eta Aquilae, an easily observed variable star with a range of 0.9 magnitude. It is a Cepheid variable, which means that the change in its brightness is caused by an actual expansion and contraction of the star. Eta Aquilae is what astronomers call "a good clock," in other words, its brightness change is exceedingly regular, with a period of 7.17664 days. If you watch the star for a week, you'll see that at times it appears brighter and at other times fainter than Alshain.

The constellation Aquila has been identified as an eagle for more than three thousand years. In Greek mythology, the eagle stood by the side of the king of the gods, Zeus, in his prolonged struggle with the Titans for control of the universe. It supposedly carried Zeus' thunderbolts down to kill the Titans and also played a role in domestic affairs on Mount Olympus. One day the gods needed a new cupbearer, or waiter, to bring them fresh nectar. This task could be performed only by the most beautiful youth on Earth. Aquila was sent to find the new cupbearer and bear him to Mount Olympus. When he delivered the handsome Trojan prince Ganymede to Zeus, the king of gods was so delighted that he reserved a place for Aquila among the stars.

ber that this point of light is really two worlds, Pluto and its satellite Charon. They are closer in size than any other planet and moon in the solar system.

August is the last month that Comet Tempel 1 is brighter than 10th magnitude and thus an easy target for small scope owners. The comet was closest to the Sun last month and is now on the outward-bound leg of its orbit, heading for the depths of space.

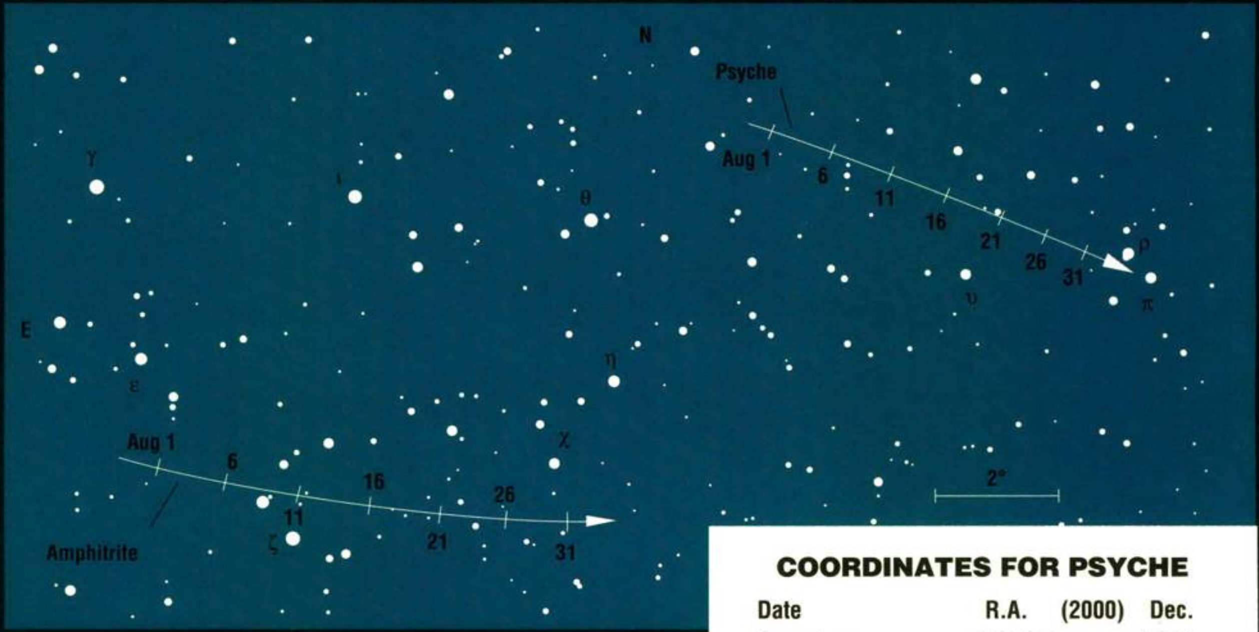
Two asteroids, 29 Amphitrite and 16 Psyche, reach opposition near each other this month in the constellation Capricornus. Use binoculars or a small telescope to discern these starlike objects by noting their motion in front of the fixed stars. Now that the Galileo spacecraft has shown that asteroid 243 Ida has its own bona fide satellite, it's worth pondering, while gazing at Amphitrite and Psyche, what secrets they have yet to reveal.

Finally, turn your gaze toward two deep-sky objects best seen through a small telescope. M16, the Eagle Nebula in the constellation Serpens, is a star cluster immersed in a nebula, while M17, the Omega Nebula in Sagittarius, appears as a large diffuse nebula.

August's Planets

After the Moon, **Venus** is by far the most conspicuous object in the evening sky. This brilliant beacon shines at magnitude −4.3 from its position near the western horizon after sunset. If you follow the progress of Venus with a telescope this month, you will see its disk grow from 19" to 26" across as its phase dwindles from 60 percent to 45 percent lit.

Giant **Jupiter** appears only about a tenth as bright as Venus, though it's still the second-brightest point of light in the night sky. You can spot it easily above and to the left of Venus after sunset. Jupiter



A Trio of Asteroids

August provides three reasonably bright asteroids for your viewing pleasure. First up is 16 Psyche, which reaches opposition on the 3rd when it glows at magnitude 9.4 as it cruises through Capricornus. Flying formation with Psyche is 29 Amphitrite, which lies about 10° southeast of Psyche. At opposition on August 10, it glows a bit brighter than its cousin Psyche, at magnitude 9.1.

Although Psyche measures 155 miles across (250 km) and Amphitrite is 120 miles in diameter (195 km), all you'll see in your telescope's eyepiece is a point of light. You can use the finder chart or table of coordinates to locate these objects and the same technique you used to locate Pluto.

The third asteroid this month is 10th-magnitude 1620 Geographos. This fast-moving near-Earth asteroid is special now — it's making its closest approach to Earth in at least two centuries. So we've devoted a separate article to it (see "Seeking the Speedy Geographos" on page 58).

COORDINATES FOR PSYCHE

Date	R.A. (2000)	Dec.
August 1	20h53.3m	−15°47'
August 6	20h49.2m	−16°09'
August 11	20h45.1m	−16°31'
August 16	20h41.3m	−16°52'
August 21	20h37.7m	−17°12'
August 26	20h34.5m	−17°31'
August 31	20h31.8m	−17°48'

COORDINATES FOR AMPHITRITE

Date	R.A. (2000)	Dec.
August 1	21h36.0m	−21°14'
August 6	21h31.2m	−21°29'
August 11	21h26.3m	−21°42'
August 16	21h21.3m	−21°53'
August 21	21h16.5m	−22°02'
August 26	21h11.9m	−22°07'
August 31	21h07.8m	−22°09'

shines at magnitude –2.0 in August against the background stars of Virgo.

Jupiter reached opposition last April, when Earth passed between it and the Sun. In August, as the distance between our two worlds increases, the apparent size of Jupiter shrinks from 37" to 34". Those who have grown familiar with the spots and swirls in Jupiter's dense atmosphere may see something unusual this month in response to last month's impacts of the fragments of Comet Shoemaker-Levy 9. (See "The End of the Line" on page 72 for more on what you might see of the comet crash.)

Uranus and **Neptune**, both in Sagittarius, appear in the southeast shortly after sunset. Both planets reached opposition in July, so they are still about as bright as they get. This month Uranus shines at magnitude 5.6 and Neptune at magnitude 7.9.

Although you won't see it immediately after sunset in early August, **Saturn** rises during evening twilight. At magnitude 0.6, it easily outshines the stars of its host constellation, Aquarius. The Ringed Planet reaches opposition in early September, so now is a good time to start observing it. This month the planet's equatorial diameter measures 19" and its rings, which tilt 6° to our line of sight, span 43".

The only prominent planet not visible in the evening hours this month is **Mars**. But you can find the Red Planet in the east before dawn, where it shines at magnitude 1.2 in a region of the sky littered with bright stars. At the beginning of August, Mars lies in the constellation Taurus, but it soon crosses into Gemini. On August 19, it passes less than 1° south of the bright open star cluster M35. And the waning crescent Moon passes just 3° south of Mars on the morning of August 3.

Mercury can't be seen this month. It is traveling behind the Sun as seen from Earth, reaching superior conjunction on August 12/13. ☐

Deborah Byrd writes and produces the daily "Earth and Sky" radio series. Rick Shaffer is an engineer and writer living in Southern California.

Two Bright Emission Nebulae

The region of Sagittarius, Scorpius, and Serpens is rich in the star clusters and nebulae that populate our Galaxy's disk in this direction. Two that are especially easy to find are M17 in Sagittarius and M16 in Serpens. Both are emission nebulae, large collections of gas and dust that are condensing to form stars. You'll likely never forget your first view of either of these outstanding objects.

You can find M17 9° due north of the top of the Teapot asterism in Sagittarius. It's bright enough that you'll see it easily with your naked eye from a dark site. And it's big enough, about the angular diameter of the Full Moon, that you can see it fairly well in binoculars.

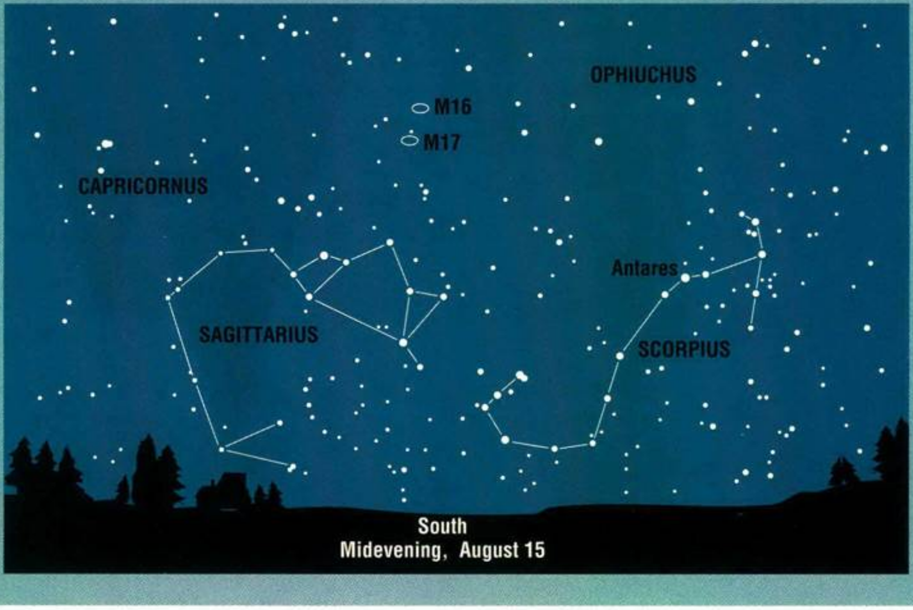
M17 has a distinctive bar-and-sickle shape that reminds some people of the Greek letter omega. Other observers see a swan in this shape. Upward of 35 stars are apparently associated with this nebula, some of which provide the power to excite the surrounding cloud of gas that composes the nebula. It's about 6,000 light-years away and 10 to 12 light-years across.

Just over the border in the constellation Serpens from M17 lies M16, the Eagle Nebula. This object is a bright star cluster with considerable subtle nebulosity. Its subtlety becomes obvious in long-exposure photographs, which reveal all manner of exquisite turbulence-caused details.

The Eagle Nebula is a bit farther away than M17 is, and there's more obscuring matter between us and it, so it appears fainter than M17. The presence of the rich open star cluster embedded in the Eagle Nebula suggests that it is significantly older than M17, because more of the nebula's gas has been converted into stars.

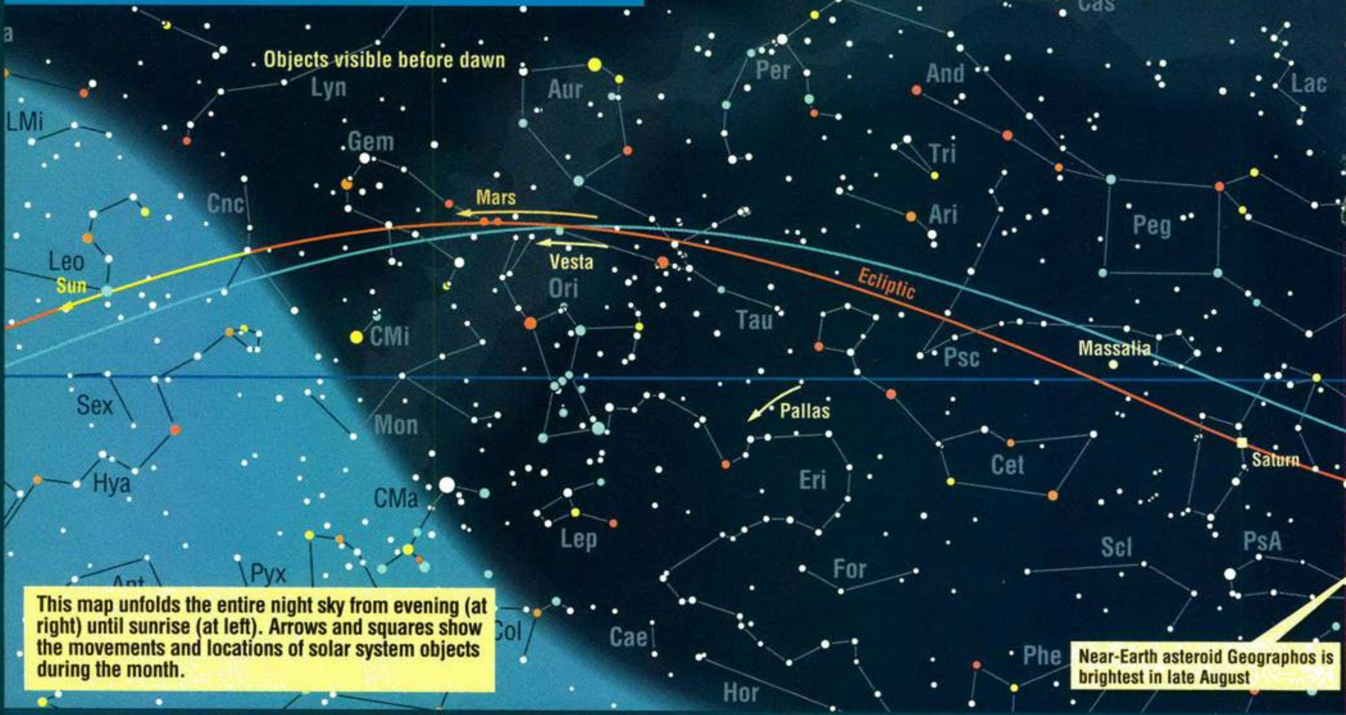
These two objects are bright enough that you can get a good view at whatever power your eyepieces and the seeing will provide. A nebula filter will help you see the more subtle outlying details of these two fine nebulae.

John Gleason



SKY ALMANAC

AUGUST 1994


Objects visible before dawn
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Vesta
Ori
Ecliptic
Tau
CMi
Psc
Massalia
Sex
Mon
Pallas
Cet
Saturn
Hya
CMa
Eri
Lep
Scl
PsA
Pyx
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For
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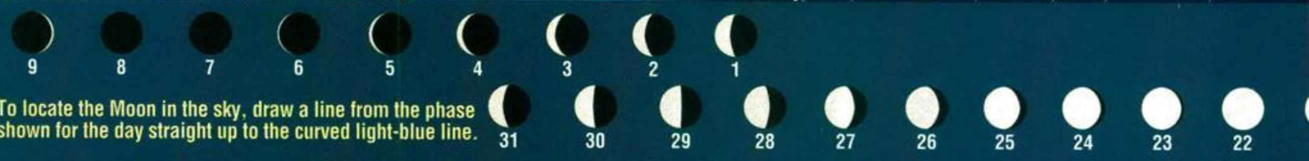
Hor

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.

Near-Earth asteroid Geographos is brightest in late August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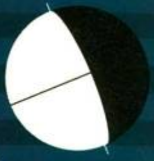
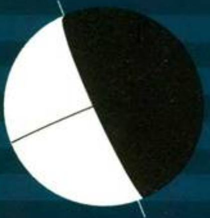
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

10"

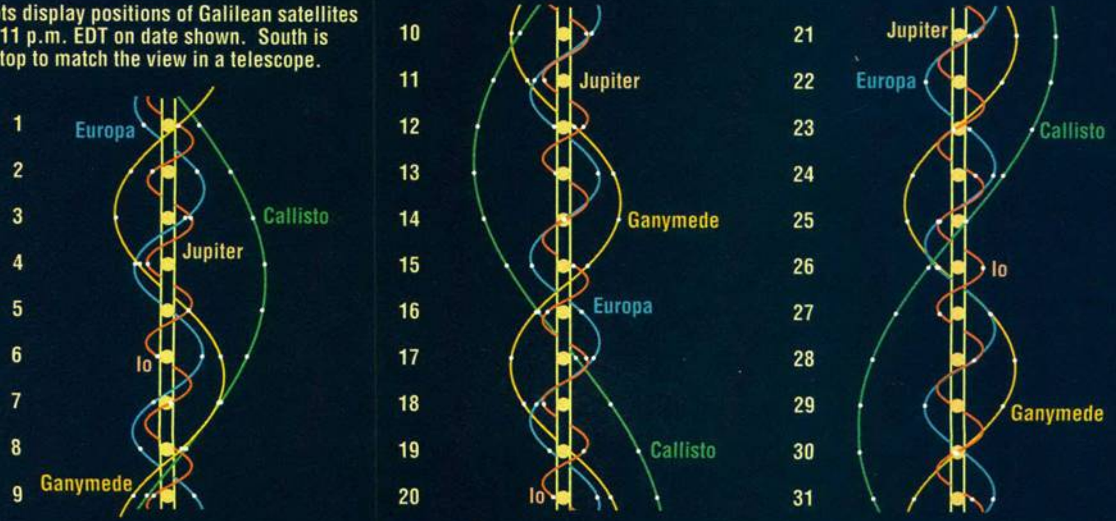
S W E N

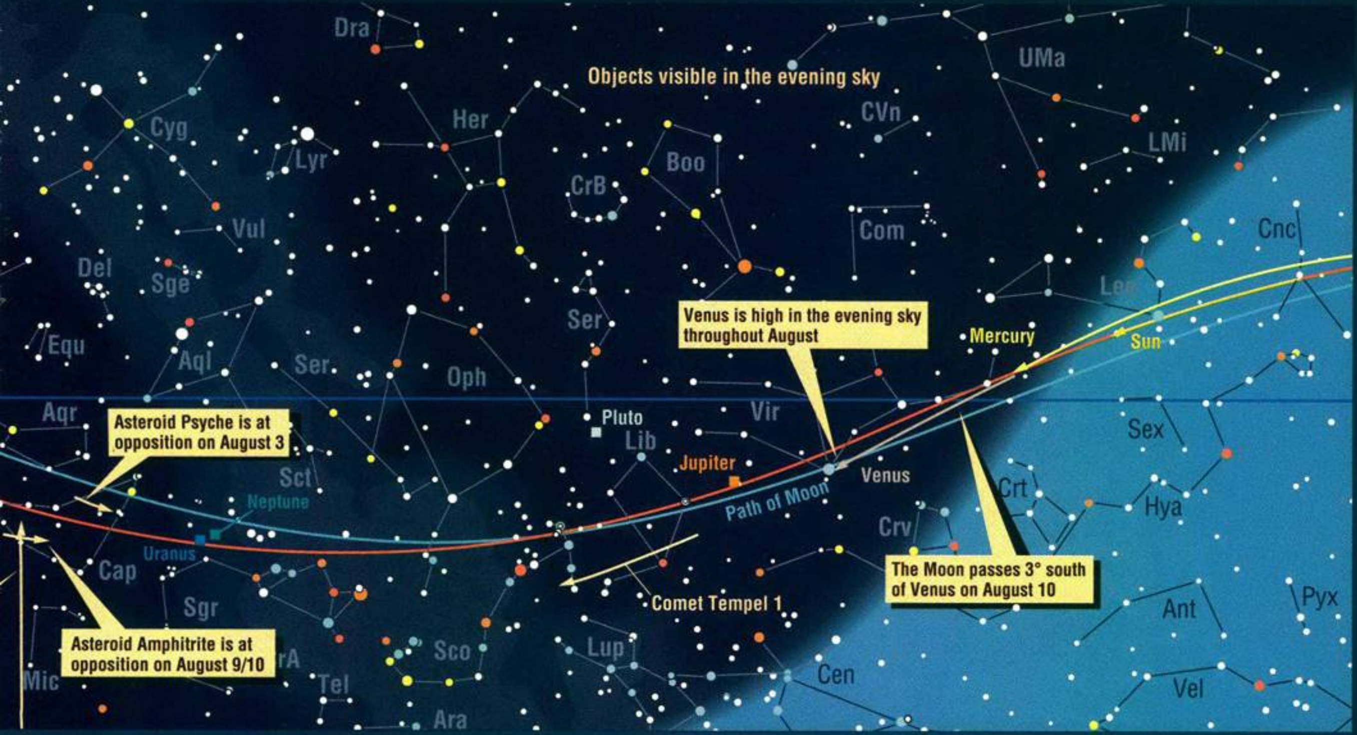
PLANETS	MERCURY	MERCURY	VENUS	VENUS	MARS
Date	August 1	August 31	August 1	August 31	August 15
Magnitude	–1.2	–0.5	–4.2	–4.4	1.2
Angular Size	5.6"	5.2"	19.1"	26.3"	5.1"
Illumination	84%	89%	60%	45%	92%
Distance (AU) from Earth	1.197	1.306	0.873	0.635	1.853
Distance (AU) from Sun	0.308	0.434	0.726	0.728	1.486
Right Ascension (2000.0)	7h51.0m	11h36.5m	11h34.8m	13h22.3m	5h55.2m
Declination (2000.0)	21°37'	3°14'	3°01'	–11°28'	23°36'

JUPITER'S MOONS

Dots display positions of Galilean satellites at 11 p.m. EDT on date shown. South is at top to match the view in a telescope.

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Jupiter
Venus
Neptune
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Crt
Hya
Uranus
Crv
Cap
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Comet Tempel 1
Ant
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Sco
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Cen
Vel
Ara

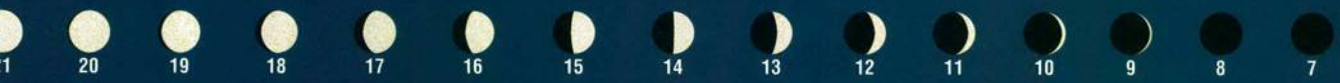
Objects visible in the evening sky

Venus is high in the evening sky throughout August

Asteroid Psyche is at opposition on August 3

The Moon passes 3° south of Venus on August 10

Asteroid Amphitrite is at opposition on August 9/10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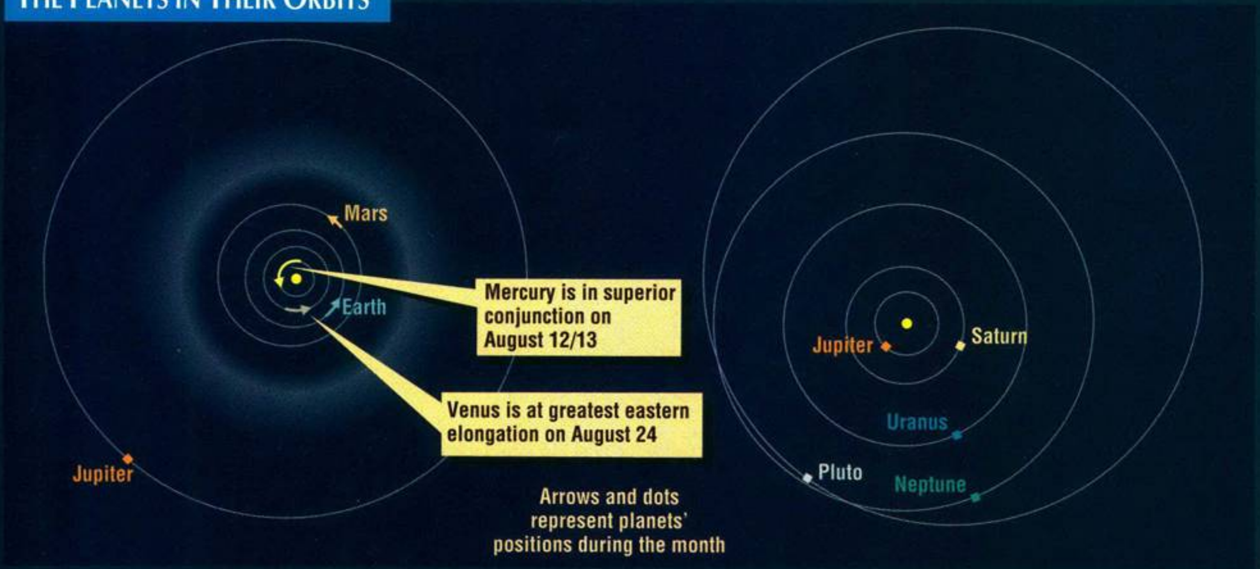
JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
August 15	August 15	August 15	August 15	August 15
−2.0	0.6	5.6	7.9	13.7
35.3"	18.9"	3.7"	2.3"	0.1"
99%	100%	100%	100%	100%
5.575	8.754	18.775	29.302	29.719
5.412	9.720	19.669	30.176	29.793
14h22.2m	22h50.6m	19h41.1m	19h31.4m	15h45.3m
−13°05'	−9°28'	−21°57'	−21°10'	−5°38'

THE PLANETS IN THEIR ORBITS


Mars
Earth
Jupiter
Jupiter
Saturn
Uranus
Pluto
Neptune

Mercury is in superior conjunction on August 12/13

Venus is at greatest eastern elongation on August 24

Arrows and dots represent planets' positions during the month

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Superb for long distance nature observation and astronomy. The image quality will amaze you even when compared to much higher priced binoculars. Fully multi-coated optics provide high-fidelity true color images without ghosting or other aberrations. Long 16mm eye relief and roll-back eyecups for eyeglass wearers. BAK-4 prisms. Weighs just 28 oz. Includes deluxe hard carrying case, rain shield, lens caps, and straps.

10x50 5.3° field of view #9353 **$219** (5.19)
NEW! 7X50 6.0° field of view #9355 **$219** (5.19)

Orion® 70mm FMC Giants

The standard for hand-holdable astronomy binoculars. Fully Multi-Coated. 33% lighter—weighs only 58 oz.—yet the same brightness and 7mm exit pupil as our 11x80 MC model. Superior 'BCF' body design. Includes: soft rubber eyecaps, tripod mounting adapter, durable hard carrying case, lens caps and straps.

10x70 #9501 **$319** (6.97)
14X70 #9494 **$319** (6.97)

80mm FMC Giant Binoculars

20% more light transmission than ordinary "fully coated" binoculars. Fully Multi-Coated optics and superior BAK-4 prisms provide fantastic contrast and greatly improved edge sharpness.

11x80 MC- Brightest, widest field available. Ideal for deep-space observation under dark skies. Hand-holdable. #9502 **$439** (8.05)

16x80 MC- 45% higher power, excellent for astronomy and daytime observation. Tripod recommended. #9496 **$439** (8.05)

20x80 MC- Highest power model perfect for smaller deep-space objects and long range daytime views. Tripod required. #9498 **$439** (8.05)

Orion Standard Series 80mm Giant Binoculars

Made in the same factory as name brand models selling for much more! Fully coated optics with multi-coatings and BAK-4 prisms. Smooth center focus design. Soft rubber fold-back eyecups. Include lens caps, straps, and carrying case.

11x80 model Bright 7.1mm exit pupil, 4.2° field of view #9480 **$349** (7.76)

16x80 model 5mm exit pupil, 3.5° field of view. #9482 **$349** (7.76)

SuperGiant™ 100mm Binos

Gigantic, almost 4" lenses gather 156% of the light of 80mm binoculars. Individual eyepiece focus, fully Multi-Coated optics and BAK-4 prisms. Tripod mounting plate, metal-clad case. Weight 7.5 lbs., height 13.5".

Sale!
14x100 #9495 **$799** (29.00)
25x100 #9497 **$799** (29.00)
Shipped by FedEx only.

Observing Aids

Eyepiece & Accessory Cases

With patented unbreakable latches, die-cut foam inserts. (Inside Dimensions shown)

Small Case (shown) 11"x7"x3" #5951 **$17.95** (2.78)
Medium Case 12.5"x9"x5" #5952 **$26.95** (3.36)
Large Case 16"x11"x5" #5953 **$49.95** (5.19)

Orion® FlexiShield™ Dew Caps

Forms into a tube with Velcro closure, opens flat for storage and travel. Models to fit most telescopes.

8" Celestron/Meade SC #4200 **$44.95** (2.98)

Other sizes available for scopes 3.5" to 14" —See our catalog for details

Orion® Dew Zapper

Gently replaces lost heat, a sure-fire cure for dew problems.

8" Dew Zappers—fit all Meade & Celestron 8" SCs DC #3503, AC #3504 **$47.95** (2.98)
10" Dew Zappers—fit all Meade 10" SCs DC #3506, AC #3508 **$54.95** (2.98)
11" Dew Zappers—fit all Celestron 11" SCs DC #3510, AC #3512 **$59.95** (2.98)

Scope Saver Telescope Covers

Keep the dust and dew away with these waterproof nylon covers; drawstring closure with cord lock.

8"Model #15130 **$33.95** (2.43)

10"-11" Model Fits Meade 10" and Celestron 11" #15131 **$39.95** (2.43)

Now available for Deep Space Explorers!
Ask about other sizes.

Observer's Chairs

Standard Model—Adjustable height center column and padded seat. #5935 **$39.95** (4.70)
Deluxe Model—Built for professional musicians. Extra heavy duty. #5934 **$89.95** (8.02)

Night Vision Flashlights

An essential accessory for astronomers. Choose from our wide selection.

Nitewriter Pen #5709 **$8.95** (1.79)
Hands-Free Flex Light #5707 **$17.95** (2.43)
Starlite LED Flashlight #5714 **$24.95** (2.43)
Celestron LED Flashlight #5720 **$21.95** (2.43)

Filters

Glass Solar Filters

High-quality optical glass filters, for superb images of the sun with your telescope. Triple-coated with advanced scratch-resistant stainless steel alloy. Great for both visual and photographic use. Slide fits over the front of your telescope.

For 8" SCs #7713 **$144** (4.05)
For 10" SCs #7715 **$162** (4.05)

NEW! *Solar glass filters for Deep Space Explorer reflectors. Many other sizes available—see our free catalog for details.*

Moon Filters

Cuts 87% of the light from the Moon. Reduces glare by uniformly reducing light transmitted over the entire spectrum.

.965" #5664, 1.25" #5662 **$14.95** (2.43)

Color Eyepiece Filters

Made from absolutely the highest quality photographic-grade precision-ground optical glass, anti-reflection coated. Ideal for contrast-enhancing planetary and lunar observations and photography with any telescope. The black anodized, machined aluminum cells thread into any standard eyepieces, or into our universal camera adapters.

.965" Basic Set of 4 Filters #80A Blue, #58 Green, #25 Red, #15 Yellow. #5510 **$46.95 set** (2.98)

1.25" Basic Set of 4 *#80A Blue, #58 Green, #25 Red, #15 Yellow.* #5514

1.25" Expansion Set of 4 *#21 Orange, #47 Violet, #11 Yellow-Green, #82A Very Pale Blue.* #5516

1.25" Advanced Set of 4 *#8 Light Yellow, #23A Light Red, #38A Deep Blue, #56 Light Green.* #5570

$48.95 each set (2.98)

Deluxe Set of 8 Filters for 1.25" Includes all the filters in our basic and expansion filter sets. #5517 **$84.95 set** (3.45)

Full Set of 12 Filters for 1.25" Includes Basic Set, Expansion Set, Advanced Set. #5575 **$124 set** (3.67)

2" Set of 4 Includes #80A Blue, #58 Green, #21 Orange and #12 Yellow. #5513 **$89.95 set** (2.98)

Individual .965", 1.25" & 2" Filters- Many colors available, see our catalog for details.

SkyGlow™ Light Pollution Filters

The finest available, SkyGlow™ filters from Orion make detailed deep-sky observing possible from light polluted city and suburban locations. Sophisticate multi-layer technology actually absorbs light pollution! Greater blocking and higher transmission than competitive models. See catalog for details..

SkyGlow UltraBlock Filters–
Visual Only
For severely light polluted areas and faint nebulae.

1.25" UltraBlock Filter–fits 1.25" eyepieces. #5654 **$97.50** (3.45)
2" UltraBlock Filter–fits 2" eyepieces. #5657 **$119** (3.67)
.965" UltraBlock Filter–fits .965" eyepieces. #5655 **$77.50** (3.67)
SC UltraBlock Filter–fits rear cell of Meade & Celestron SC scopes. #5656 **$129** (3.67)

SkyGlow Broadband Filters—Photographic and Visual
For use in slight to moderately light polluted areas.

1.25" Broadband Filter–fits 1.25" eyepieces. #5660 **$69.95** (3.45)
SC Broadband Filter–fits rear cell of Meade & Celestron SC scopes. #5658 **$89.95** (3.45)
52mm Broadband Filter–For 52mm camera lenses. (Adapter rings available for other diameters.) #5668 **$87.50** (3.45)
2" Broadband Filter–fits 2" eyepieces. #5659 **$109** (3.45)
.965" Broadband Filter–fits .965" eyepieces. #5661 **$49.95** (2.98)

Accessories

Call Toll-Free For Our Huge 100 Page Catalog and See Even More!
Orion Accessories are absolutely guaranteed to be the finest quality available. Compare them side-by-side with "famous name" products! We buy direct from many of the same sources, always specify the highest quality, and pass along the savings to you! 100% satisfaction guaranteed!

Universal Camera Adapters

For prime focus or eyepiece projection astrophotography.

.965" #5268 **$26.95** (2.98)

1.25" #5264 **$28.50** (2.98)

Hybrid 1.25"/.965" #8782 **$28.50** (2.98)

Variable Power Camera Adapter

Allows variable projection distances during eyepiece projection photography. For 1.25" eyepiece holders.
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Attaches to your photo tripod pan head. 2 slow motion control knobs to make precision adjustments in altitude and altazimuth. Very handy for tracking planets, the Moon, etc. with refractor telescopes and small spotting scopes. Attaches with a standard 1/4-20 thread.
#7012 **$59.95** (2.98)

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12 3/4" flexible cable, for tracking at high powers. Buy 2, one for each axis.
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Tele-Extenders for SC Scopes

For high powered photography with your Meade, Celestron 4", 8", 10", 11", 14" Schmidt-Cassegrain.
Standard Tele-Extender #5125 **$27.95** (2.98)

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T-Adapters for SC and MAK

Threads to rear cell of telescope, requires t-ring for your camera model. ***for SC*** #5116 **$26.50** (2.98)

for C-90 #7115 **$29.95** (2.98)

T-Rings for all 35mm Cameras

Available for many different camera types, call toll-free or see our catalog for your particular model.

45° Erect Image Diagonal Prisms

See the world as it really is with Orion's 45° erect image diagonal. Ideal for all refractors and compound telescopes used for terrestrial viewing.
1.25" Diagonal #8790
.965" Diagonal #8791
Hybrid 1.25"/.965" Diagonal #8792
$44.95 (3.45)

90° Star Diagonal Prisms

Orion's multi-coated diagonals let you view at a right angle from the direction your telescope is pointing. The image is backward. Ideal for refractors and Schmidt-Cassegrains used for astronomical viewing.

1.25" Star Diagonal #8763 **$48.95** (2.98)
.965" Star Diagonal #8761 **$29.95** (2.98)

Hybrid 1.25"/.965" Star Diagonal
#14008 **$31.50** (2.98)

Orion Ultra™ 2" Diagonals

Your SC or refractor deserves the finest. Both models are the finest optical quality and use the best coatings available.
2" Prism Diagonal–Absolutely the finest quality multi-coated 2" prism for highest light transmission.

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For refractors #8773
For Schmidt-Cass. #8772 **$99.95** (3.45)

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any Sky Wizard when purchased with any telescope installation package!

Electronic Finder & Sky Catalog

Let Sky Wizard do the work, while you relax and have fun observing!

- Find any celestial subject in 15 seconds!
- One minute setup — no polar alignment or levelling.
- Observe hundreds of objects in a few hours!
- For ANY telescope, with or without a motor drive. *Even altazimuth or Dobsonian scopes!*
- Digital display of celestial coordinates (RA & Dec).
- Built-in electronic sky catalog — find subjects by their common catalog name, not their coordinates. Complete with object descriptions.
- Powered by a single 9v battery. Weighs just 6 oz!

Sky Wizard Model 1
Includes the Messier Deep Space Catalog of 110 objects, 28 bright stars, and the planets. #7801 **$199** (4.11)

Sky Wizard Model 2
Huge 2100+ object database, plus a user catalog to store 27 objects of your choice.
#7802 **$319** (4.44)

Sky Wizard Model 3
Gigantic 10,000 object database, expanded subject descriptions, RS-232 port.
#7803 **$469** (6.78)

Complete system requires Sky Wizard Model 1, 2 or 3 and a telescope installation package, sold separately.

Installation Packages
Includes 2 encoders, all required mounting hardware and brackets, connecting cables, and complete illustrated instructions.
Installation packages are available for most telescope models. Call for details.

starting at **$177** (5.29)

Encoders and cables also available separately for custom installations. Call for details.

Orion Off-Axis Guider

Allows you to observe a guide star during photography. Multi-coated.
#5144 **$69.50** (3.45)

Orion UltraGuider

Wide-range lateral prism adjustment; precision helical focusing; adjustable camera focal plane position.
#5139 **$119** (4.19)

110v Motor Drive for Refractors

Fits Orion equatorial mounts, many others. Plugs into any standard AC outlet.
#17001 **$72.50** (3.95)

12 Amp Hour Porta Pac Battery

Ideal for high power-consuming accessories. With carrying case. Weighs only 10 lbs.
#2354 **$109** (8.97)

Eyepieces

See Our Huge 100 Page Catalog for Many More! Including a Fantastic Selection of Name Brand Eyepieces!
2
3b
3c
3a
5
1
New!
40mm
✧Sirius
Plössl

1 ✧ *Sirius*™ *Plössl 1.25" Eyepieces*

Fantastic Name-Brand Quality Eyepieces at an Incredible Low Price!

You could pay nearly twice the price for "famous name" Plössl eyepieces, but we don't think you'll be able to tell the difference if you compare them to these fantastic eyepieces!
Sirius Plössls are top-quality, 50° apparent field (43° 40mm) eyepieces with extremely sharp images of impressively high contrast. Ideal for all types of telescopes. The Classic 4-element Plössl design is renowned for its fantastic performance and has become the standard by which all other eyepieces are compared.

The Fully Magnesium fluoride coated optics are mounted in precision black anodized aluminum housings with chrome-plated brass 1.25" barrels for durability and precision fit.

25mm #8530, ***17mm*** #8531,
10mm #8532, ***7.5mm*** #8533 **$57.95 ea.** (3.45)

New! ***40mm*** #8529 **$79.95** (3.67)

Case only #5911 **$12.95** (2.19)

SPECIAL OFFER–Buy Two or More and Save!
- *Any 2 .... $10 off (Save $5 ea.)*
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- *Any 4 .... $60 off (Save $15 ea.)*
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Bonus—Free case with purchase of 2 or more!

Buy Two Get One FREE!

Limited Time Special Offer!

Buy any two Ultrascopic eyepieces and get your choice of a 10mm or 7.5mm free! *Limited offer subject to stock availability.*

2 Orion 5-Element Ultrascopic™ Eyepieces

With superb Ultra™ Multi-Coatings!
Made for Orion by Japan's finest lens maker, Ultrascopic eyepieces yield the highest contrast, greatest light transmission, and best overall image fidelity obtainable. With a superior 5-element design and Ultra™ Multi-Coatings on *every* surface, they achieve a level of performance "name brand" 4-element models can't match. Wide 52° flat field of view. Removeable coutoured rubber eyeguard. The 5mm and 3.8mm feature advanced 7-element designs which yield surprisingly long eye relief. Absolutely guaranteed to knock your socks off!

3 Orion Explorer™ Multi-Coated 1.25" & .965" Eyepieces

These fine quality multi-coated eyepieces offer great performance at Orion's low direct-discount price. Three different optical designs are incorporated, to maximize efficiency in the various focal lengths. Black anodized, internally blackened, threaded for filters (except 40mm .965").

b *1.25" Orthoscopic*
5mm #8500, **7mm** #8502, **9mm** #8504, **12.5mm** #8506, **18mm** #8524, **25mm** #8526
$54.95 each (2.98)

c *1.25" Kellner*
6mm #8536, **9mm** #8538, **12mm** #8540, **18mm** #8508, **25mm** #8510, **40mm** #8512
$39.95 each (2.98)

a *.965 Orthoscopic*
5mm #8580, **7mm** #8581, **9mm** #8582, **12.5mm** #8583 **$49.50 each** (2.98)

a *.965 Kellner & Achromatic Huygenien*
K 18mm #8584, **K 25mm** #8585, **AH 40mm** #8586
$37.50 each (2.98)

Medium-High Power 5-element
20mm #8566, **15mm** #8568, **10mm** #8570, **7.5mm** #8572 **$89.95 ea.** (3.45)

Wide Field 5-element
25mm #8564 **$99.95** (3.45)
30mm #8562, **35mm** #8560 **$109 ea.** (3.45)

***High Power 7-element** —Long Eye Relief*
5mm #8574, **3.8mm** #8576 **$89.95** (3.45)

Illuminated Reticle Eyepieces

A necessity for long exposure astrophotography and very useful for polar alignment.

12.5mm Plössl Illuminated Reticle 1.25"
Illuminator has fully adjustable brightness. Features double crossline reticle. Batteries included.
#8484 **$109** (3.45)

9mm Orthoscopic Illuminated Reticle 1.25"
Adjustable brightness illuminator. 'Bull's-eye within crosshairs' reticle. Needs 2 SR-44 batteries, not included.
#8488 **$119** (3.67))

12mm Kellner Illuminated Reticle 1.25"
Features double crossline reticle and red LED illuminator. Plugs into power panel drive bases.
#8482 **$74.95** (3.45)

12mm Kellner Illuminated Reticle 1.25"
Same as 8482 above except has a wireless illuminator. Needs 2 SR-44 batteries, not included.
#8481 **$94.95** (3.45)

SR-44 Batteries (pkg. of 2) #2360 **$5.95** (1.79)

5 UltraZoom™ 7–21mm

The finest zoom you can buy for your 1.25" telescope. For astronomy or terrestrial observing. 65°-35° field. Fully coated.
#8556 **$169** (3.67)

Barlow Lenses

Orion offers a large selection of barlow lenses, allowing you to double or even triple the power of your eyepieces, maximizing the versatility of your collection. Available in .965", 1.25" and 2" diameters.

Fully Baffled 2x Barlow
Multi-coated, with internal baffling to block transmission of stray light. Premium performance at a remarkable price.
.965" #8740 **$34.95** (2.98)
1.25" #8746 **$44.95** (2.98)
2" #8724 **$89.95** (3.95)

Ultrascopic 2x Fully Multi-Coated Barlow
3-element Ultrascopic lens for superior images and precise color correction. Fully multi-coated optics, black anodized barrel. 1.25 barrel.
#8750 **$64.95** (3.45)

VariPower 2-3x Barlow
Allows you to adjust the magnification factor of the barlow by sliding the internal cell along a calibrated scale. Fully multi-coated optics. 1.25" barrel.
#8748 **$57.95** (3.45)

Shorty Barlows **Sale!**

The short bodies allow extra versatility: provides 2x magnification when the eyepiece is inserted directly, and 3x magnification when positioned before the diagonal on a refractor or SC. Will work in all telescopes, including those where longer barlows won't work.
.965" #8710 **$39.95** (2.98)
1.25" #8711 **$49.95** (3.45)

Quality Components for Building or Upgrading

Parabolic Primary Mirrors

Excellent hand-figured parabolic mirrors guaranteed to meet theoretical limits of resolution. Fine polished, coated twice: with Aluminum and Silicon monoxide. Very competitively priced! *See catalog for pricing.*

Standard Primary Mirrors

Made from fine soda-lime plate glass, 1:8 thickness ratio. Guaranteed 1/8 wave. Sizes: 6" f/8, 8" f/6, 10" f/4.5, 12.5" f/6.

Pyrex Low Expansion Mirrors

Made from fine annealed Pyrex brand low expansion glass, 1:8 thickness ratio. Guaranteed 1/10 wave. Available with standard or 94% reflectivity Enhanced Aluminum coatings. Sizes: 6" f/5, 6" f/8, 8" f/6, 10" f/4.5, 10" f/6, 12.5" f/6.

Elliptical Secondary Mirrors

Made from fine annealed Pyrex brand glass, aluminized and SiO overcoated. Guaranteed 1/10 wave accuracy. Available with standard or high reflectivity Enhanced Aluminum coatings. Nine sizes from 1.00 to 4.00" minor axis.
See catalog for pricing.

6x30 Achromatic Finder Scopes

6x30mm—Same unit used on $1000+ "big name" telescopes. With 2-ring metal bracket, fits scopes 6"-12".
#13023 (white) **$49.95** (3.41)

6x30mm Right Angle—90° prism for right-angle viewing. Includes bracket.
#13021 (white) **$64.95** (3.41)

Large Aperture Finder Scopes

These are high-quality finders at incredibly low prices! Fully coated wide field achromatic optics with adjustable focus. Precision crosshairs. White or black enameled metal tube. (Mounts sold separatly.)

8x50mm—2.7x light grasp of 30mm models. Bright 6.25mm exit pupil.
#7090 (white) #7094 (black) **$64.95** (3.41)

8x50mm Illuminated—Wireless illuminator with adjustable brightness.
#7092 (white) #7096 (black) **$89.95** (3.41)

9x60mm — 44% more light grasp than 50mm models.
#7091 (white) #7095 (black)
$89.95 (3.41)

9x60mm Illuminated—Wireless illuminator with adjustable brightness.
#7093 (white) #7097 (black)
$129 (3.41)

Superb Dovetail Aluminum Mounts for 50mm and 60mm Finder Scopes

Instantly install or remove your finder, without tools, without disturbing alignment! Black anodized, Fits any scope 6" and over including Celestron & Meade SCs. *(pictured above)*

8x50mm bracket #5040 **$34.50** (2.45)
9x60mm bracket #5041 **$39.50** (2.98)

Low-Profile Helical Focusers

Economical yet precise focusing. Ideal for fast optical systems. Cast aluminum base with threaded machined aluminum inner tube.

1.25" #13014 **$39.50** (2.45)

2.0" #13016 **$59.50** (2.98)

Rack-and-Pinion Focusers

Finest in their class! Diagonal-cut plated brass racks, oversized knurled knobs, long focus travel.
1.25" #13007 **$49.95** (2.98)
2.0" includes 1.25" adapter.
#13003 **$89.95** (3.95)

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- Call Toll-Free and charge to your MasterCard, Visa or Discover Card or send your personal check to order by mail.
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- Shipping & handling charge for UPS Ground or US Mail to lower 48 United States are listed in (parentheses) after each price. We ship to U.S. and Canada only.
- We expected the prices in this ad to be accurate for August 1994 at the time of our advertising deadline in May. Prices are subject to change or correction without notice.

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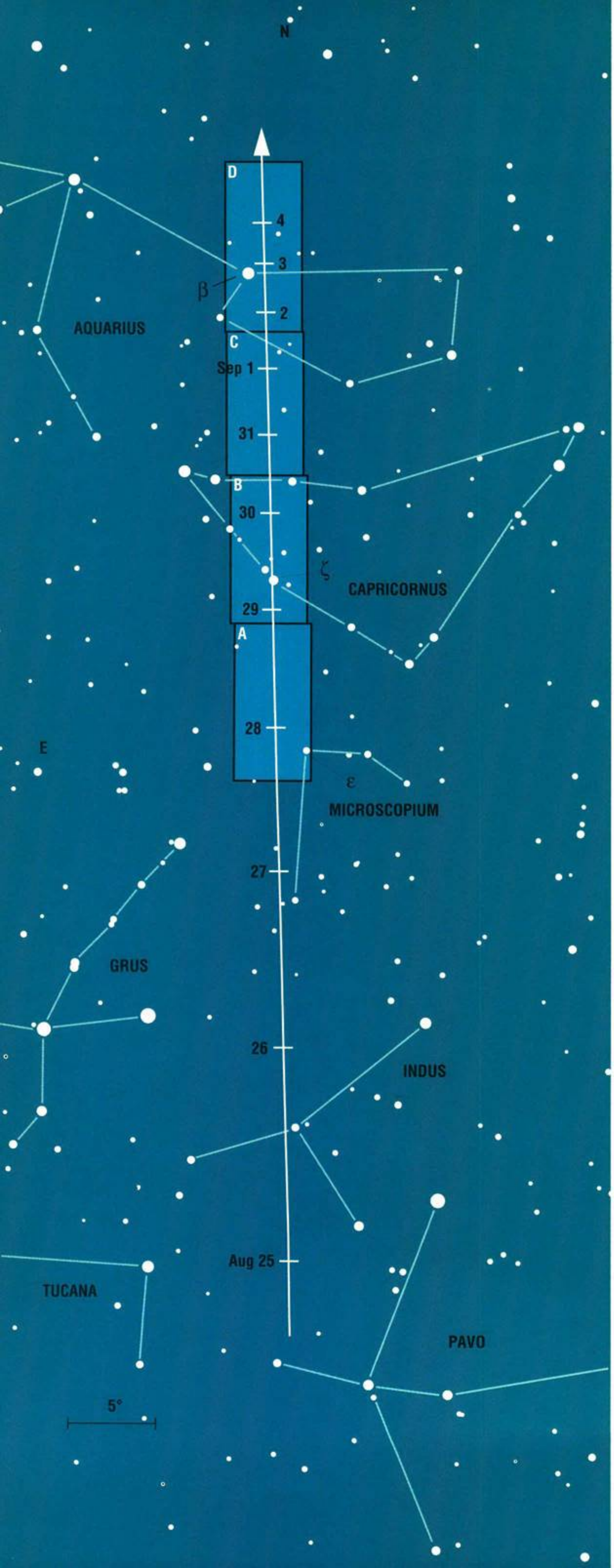


Seeking the Speedy GEOGRAPHOS

As the asteroid Geographos zips past Earth in late August, backyard observers will get their first-ever close up view of the tiny world.

by Richard Talcott

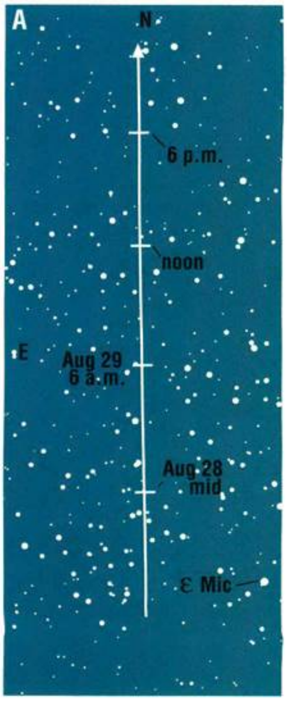
As you read this, a small chunk of rock just 2.5 miles across is hurtling toward Earth. Luckily it won't hit — it will miss us by a scant 3 million miles in late August. But this close encounter with the asteroid 1620 Geographos will still prove memorable, offering great observing opportunities to both professional and backyard astronomers.

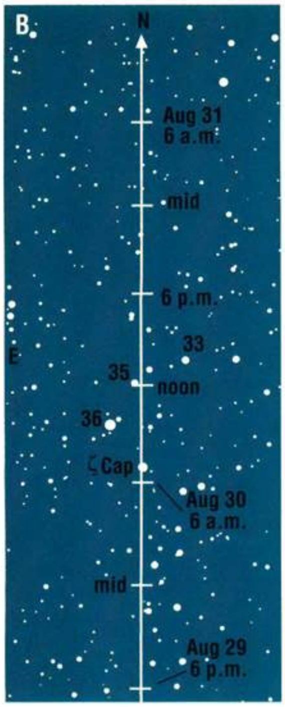
For the professionals, Geographos provides a perfect target for a closeup look at a near-Earth asteroid. Astronomers around the globe have been monitoring the light variations of Geographos since last October. Their goal: to pinpoint the asteroid's rotation rate and direction and the orientation of its spin axis in space. All this was designed to help scientists get the most out of the Clementine spacecraft's flyby of the asteroid. When mission controllers lost control of Clementine in early May, however, the flyby was off. Still, the observations have made Geographos one of the best studied of all asteroids and will aid astronomers when they image the asteroid with radar later this year.

For backyard observers, the close approach of Geographos presents a rare chance to glimpse one of the solar system's tiniest members. During late August and early September, Geographos will glow at 10th magnitude, brighter than at any time since its discovery in 1951. Over a roughly ten-day period, observers with binoculars or a small telescope can watch as the asteroid shoots from deep in the southern sky northward through the constellations Microscopium, Capricornus, and Aquarius.

A Rare Close Approach

The nearness of Geographos to Earth and its rapid motion across the sky result from an unusual orbit. It swings from outside Mars' orbit nearly into the orbit of Venus. The asteroid crosses Earth's orbit





twice every 507 days, the period of its orbit around the Sun, but rarely is Earth nearby when it does so. This year is different, however. Earth lies near the position where Geographos crosses our orbit and the two objects come closer than they have in more than 200 years (they won't be as close again for over 100 years more).

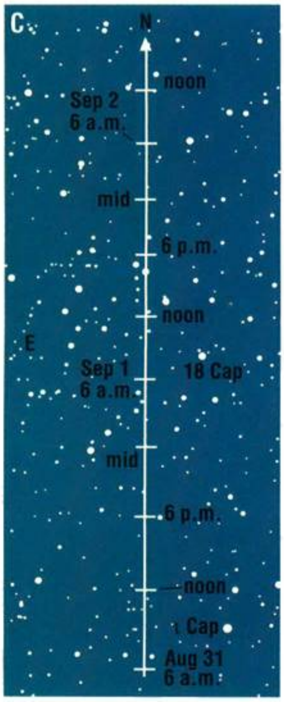
At closest approach on August 25 at 6 a.m. EDT, Geographos lies just 0.0333 astronomical unit from our planet. (One astronomical unit is the average distance between the Sun and Earth, or about 92.8 million miles.) That puts it 3.1 million miles away, just 13 times the average distance to the Moon. Despite the asteroid's puny size, from this distance it reflects enough sunlight in Earth's direction that with optical aid you can see it quite easily.

For observers in the Northern Hemisphere, Geographos remains below the horizon at the time of closest approach. But that doesn't last for long. After passing within 1° of the south celestial pole at 11 a.m. EDT on August 23 and making its closest approach to Earth on August 25, Geographos makes a beeline almost due north.

You can use the finder charts on these two pages to locate Geographos during the time it is easiest to see from the Northern Hemisphere. The large chart at left gives a wide-field view of what you can see with your naked eye, along with the position of Geographos at midnight EDT (11 p.m. CDT, 10 p.m. MDT, and 9 p.m. PDT). Use this chart to find the asteroid's approximate position and then go to the appropriate detailed finder chart to locate Geographos.

The detailed charts show stars down to magnitude 11.0, approximating the view in a pair of 7x50 or 10x50 binoculars or a 2.4-inch telescope on a clear night from a dark-sky site. The asteroid's positions are shown in Eastern Daylight Time at 6-hour intervals. If you observe at a time other than those shown, use the charts to estimate the right position.

You should be able to confirm a sighting of the asteroid by carefully comparing the object's position with that shown on the detailed charts. But to be sure, wait a few minutes.



Geographos moves so fast relative to the background stars that you should be able to detect its motion in as little as five to ten minutes, particularly if there's a star nearby to help gauge the movement. Unfortunately, even when it is moving 12° per day at closest approach (0.5° per hour, the diameter of the Full Moon, or 30" per minute), you likely won't be able to see Geographos move in real time.

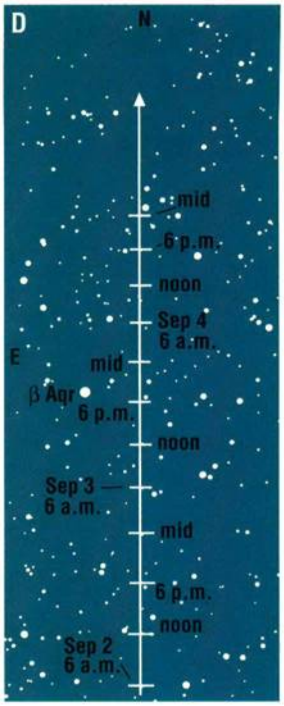
Out of the South

On the night of August 25/26, the asteroid climbs to a declination of –60°, skirting the southern horizon for an observer at 30° north latitude. But at that time it's moving north more than 10° a day, so each passing day brings it 10° higher in the sky. On the next night, you can find it racing through northern Telescopium as it reaches its peak brightness of magnitude 10.0, a level it will sustain for three nights.

Be forewarned that the magnitudes in this article are averages. Because it is irregular in shape (1 x 2.5 miles), Geographos appears brighter or fainter depending on whether more of its wide face or narrow face points toward Earth. This irregularity causes it to vary in brightness more than any other asteroid known, up to two magnitudes. So Geographos could appear a magnitude brighter or fainter than the values quoted here. And because it rotates in just 5 hours 13 minutes, its brightness can change significantly in just a few hours.

Most northern observers will get their first peek of Geographos on the night of August 27/28 or 28/29, as it makes its way north along the eastern border of Microscopium. A good marker on the evening of the 28th is the 5th-magnitude star Epsilon (ε) Microscopii. At 8 p.m. EDT, Geographos passes 1.7° east of this star.

By the next night, the asteroid resides in southern Capricornus and remains above the horizon essentially all night. It makes its closest approach to a bright star in the early morning hours of August 30, when the 10.2-magnitude asteroid passes just 2' east of 4th-magnitude Zeta (ζ) Capricorni.



Geographos continues its northward trek through Capricornus for the next few days before breaking into Aquarius on September 2. By then the asteroid's motion has slowed somewhat, but it still keeps up a good pace of about 3° per day. The last of its close stellar approaches comes on the evening of September 3, when the 11.1-magnitude asteroid passes 0.8° west of 3rd-magnitude Beta (β) Aquarii.

After that Geographos speeds away from the Sun and Earth and quickly fades from view. As it exits our vicinity, astronomers will revel in their hard-won data, and backyard observers will recall fondly their view of one of the smallest members of our solar system. Both groups undoubtedly will breathe a sigh of relief and hope that the next near-Earth asteroid will also manage to miss Earth. ☐

NEW MEADE® 16" LX200 $14,950 AT LUMICON

"What an astounding combination of high performance and low price!" Jack Marling, Ph.D., owner of LUMICON

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7" f/9 Apochromat Only $5495

7" IN STOCK!

Meade 6" f/9 Model 152ED Refractor shown with #1697 Computer.

See the Meade ad in this magazine for full specifications and product descriptions. ED = Extremely low dispersion glass which yields color-free virtually perfect images. PPEC = Permanent Periodic Error Correction "Smart Drive."

Model 102 ED 4" f/9 Apochromat & mount (add $105 P&S)	**$2195**
Model 127 ED 5" f/9 Apochromat & mount (add $125 P&S)	**$2795**
Model 152 ED 6" f/9 Apochromat & mount (add $185 P&S)	**$4495**
Model 178 ED 7" f/9 Apochromat & mount (add $215 P&S)	**$5495**
Medium format adapters ..... Mamiya 645, **$98;** Pentax 6X7,	**$98**
Med. format EASY-GUIDER™: Mamiya 645, **$298;** Pentax 6X7,	**$298**

DRIVE SYSTEMS

#1664 Electronic Drive with PPEC & 2X, 32X slewing system	**$375**
#1697 Computer Drive, 747 object computer memory, automatic slewing to desired object	**$695**
8,000 Object CNGC Library .. **$99** Polar alignment finder ..	**$99**

OPTICAL TUBE ASSEMBLIES (OTA)

Model 102 ED/OTA 4" f/9 OTA only (add $55 P&S)	**$1045**
Model 127 ED/APO-OTA 5" f/9 OTA only (add $60 P&S)	**$1595**
Model 152 ED/APO-OTA 6" f/9 OTA only (add $100 P&S)	**$2295**
Model 178 ED/APO-OTA 7" f/9 OTA only (add $120 P&S)	**$3250**
Cradle ring assem. 4" (4½" OD tube) **$135;** 5" (5½" OD tube)	**$145**
Cradle ring assem. 6" (7" OD tube) **$169;** 7" (8" OD tube)	**$219**

EQUATORIAL MOUNTS

LXD 600 mount and standard field tripod (add $60 P&S)	**$1350**
LXD 700 mount and giant field tripod (add $100 P&S)	**$2250**

NOTE: Add the indicated packing and shipping (P&S) costs to each telescope for insured UPS shipment to your door.

MEADE DOBSONIANS

Drop shipped from Meade, add shipping charge in parenthesis.

6" f/8 Starfinder Dobsonian ($39)	**$295**
8" f/6 Starfinder Dobsonian ($49)	**$395**
10" f/4.5 Starfinder Dobsonian ($69)	**$565**
12.5" f/4.8 Starfinder Dobsonian ($79)	**$765**
16" f/4.5 Starfinder Dobsonian ($45)	**$1195***

**Shipped truck freight collect; add $45 packing charge. Includes #682 focuser.*

NEW MEADE EYEPIECES

Series 3000 Plossl 1¼" eyepieces: select 5mm, 6.7mm, 9.5mm, 16mm, 25mm	**$59.95**
Select Any 3 . **$48.95 ea.;** Any 5 .	**$46.95 ea.**
Series 3000 40mm Plossl 1¼" eyepiece	**$79.95**

Shipping charges of 4-5% are extra.

NEW MEADE 16" LX200 SCHMIDT-CASSEGRAIN

8" LX200 $2295

16" LX200 $14,950

NEW Meade 8" LX200 Telescopes

See the Meade ad in this magazine for full specifications & details. **LX100 Drive**, 2X, 32X speed control with PPEC (Permanent Periodic Error Correction "Smart Drive") & dual-axis hand controller. **LX200 Drive**, Full electronic control with PPEC, 747 object computer memory and automatic computer controlled slewing to desired object. *NOTE:* A wedge is **not** needed for visual observing with the LX200 Drive. Select f/10 or f/6.3 (no extra charge) for your Schmidt-Cassegrain.

8" LX100 Schmidt-Cassegrain with wedge (add $105 P&S)	**$1995**
8" LX200 Schmidt-Cassegrain with computer (add $105 P&S)	**$2295**
Wedge for photographing with 8" LX200	**$110**
10" LX100 Schmidt-Cassegrain w/super wedge (add $145 P&S)	**$2895**
10" LX200 Schmidt-Cassegrain with computer (add $145 P&S)	**$2895**
NEW! 12" LX200 (f/10 only) with computer (add $215 P&S)	**$3995**
Super Wedge for photography with 10" or 12" LX200	**$395**
NEW! 16" LX200 f/10 w/super giant tripot (add $385 P&S)	**$14,950**
Library Option 1: 10,600 NGC, Messier, IC objects (Ver. 3.2 only)	**$99**
Library Option 2: 64,350 celestial objects (Version 3.2 only)	**$149**

OTHER SCHMIDT-CASSEGRAINS

Meade 2045D 4" f/10 with motor drive (add $40 P&S)	**$699**
Meade 2080B 8" f/10 with tripod, wedge, MCOG (add $85 P&S)	**$1149**
Model 2120B 10" f/10 w/wedge, tripod, MCOG (add $125 P&S)	**$1449**

PHOTOGRAPHY ACCESSORIES

LUMICON Cassegrain EASY-GUIDER 4", 8" only, f/6 or f/10	**$225**
LUMICON Giant EASY-GUIDER for 10" or 12" f/4-f/10 operation	**$395**

MEADE STARFINDERS

8" f/6 $699*

New 8" f/6 Meade Starfinder telescopes

See the Meade ad in this magazine for full descriptions and technical specifications for 6" to 16" Starfinders. These are complete telescope systems with motor drive, mount, finderscope and 25mm (=48X) eyepiece.

6" f/8 **Starfinder 6**(add $65 P&S)	**$599**
8" f/6 **Starfinder 8** (add $75 P&S)	**$699**
10" f/4.5 **Starfinder 10** (add $90 P&S)	**$799**
16" f/4.5 **Starfinder 16** (ship. freight COD)	**$2250**

*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated shipping charge to the price. LUMICON showroom prices are $99 higher.

ACCESSORIES

LUMICON carries the full line of Meade accessories. See the Meade ad in this magazine for detailed prices and descriptions.

LUMICON Single axis drive corrector	**$99**
LUMICON DX200 Dual-axis drive cor.	**$249**
Meade 47M Dual-axis drive corrector	**$450**
LUMICON DX2BP Dual-axis drive corrector with built-in battery pack	**$299**

LUMICON® SKY VECTOR™

Higher Performance — Lower Price

LUMICON ACCESSORIES

LUMICON, 2111 Research Dr., #5, Livemore, CA 94550 (510) 447-9570 FAX (510) 447-9589

LOW PRICE—from $399

LUMICON SKY VECTOR FEATURES:

- "GUIDE" mode leads you to object
- Digital right ascension readout to 1 min.
- Digital decl. readout to 10 arc-min.
- 4000 pulse (0.09° accuracy) encoders
- Polar alignment ***not required!***
- Motor drive ***not required!***
- Just sight two stars to align!
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
- **No need** to enter latitude, longitude, etc.

SKY VECTOR I™ $399

NEW! With over 220 object memory including the 110 Messier and 58 best NGC objects.

SKY VECTOR II™ $499

IMPROVED — Planets, Over 3,700 Objects! With size, magnitude and full visual description.

NGC SKY VECTOR™ $699

IMPROVED!—5500 Additions / Corrections

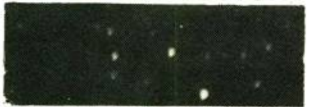
NGC-Sky Vector
OFF ON
DIM
MODE
ENTER
UP
DOWN
LUMICON

Improved NGC SKY VECTOR with over 12,000 object memory including the planets, complete, corrected RNGC catalogue, IC catalogue, P&K planetary catalogue, & much more!

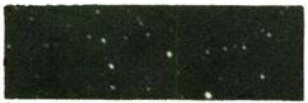
Specify Telescope Type: Meade 2045, 2080, 2120, C-8, C-11, Odyssey 8, 10, 13, 17½, Alt-Azimuth.

Ultima 8, 11 .. **add $25**, C-14 .. **add $75**

COMA CORRECTOR



Coma 1 inch off-axis 17½" f/4.5



Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. **It threads into LUMICON 2" EASY-GUIDERS for effortless installation.** This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Clear aperture = 1.8".

LUMICON 48mm Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2" EASY-GUIDER	**$169.50**
2" EASY-GUIDER (Mamiya 645)	**$199.50**
2" Adapter for Pentax 6X7	**$129.00**
2" Adapter for Hasselblad	**$229.00**
2" Adapter for Bronica SQ-A	**$175.00**
2" Extension for viewing	**$26.00**

2" DELUXE BARLOW

1.8x Multiplier Lens (2" Barlow)

LUMICON 1.8x Multiplier Lens (2" Barlow)	**$235.00**

LARGE UV/DUST SEAL

Protect the optics of your 8-14" Schmidt-Cassegrain with a UV/Dust Seal. Simply thread it onto the rear cell, then attach all normal accessories. The large size fits Meade 2120, Celestron-11 and -14 & has a high quality multi coated (removable) 72mm UV filter.

Deep-Sky Filter/Dust Seal for C-8, 2080	**$119.50**
UV/Dust Deal for Celestron C-8	**$39.00**
UV/Dust Seal for Meade 2080, 2045	**$39.00**
UV/Dust Seal (large) for Meade 2120	**$89.50**
UV/Dust Seal for Celestron-11, -14	**$89.50**

LOW PROFILE FOCUSERS New! Thread-on for Odyssey

FROM $59.50

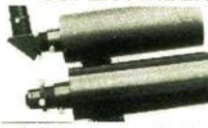
LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.

Select your desired base-plate shape! Coulter Odyssey (thread-on installation), Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 21" OD.

LUMICON 1¼" Helical Focuser	**$59.50**
LUMICON 2" Helical Focuser 1½" high	**$65.00**
LUMICON Non-rotating Helical Focuser	**$129.00**
2" Astro Systems focuser, only 2" high	**$139.00**
3 handles for non-rotating focuser	**$12.95**
2"/1¼" adapter w/48mm filter threads	**$20.00**
2" LUMICON EASY-GUIDER	**$169.50**

LUMICON 50mm, 80mm SUPER-FINDER™



Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

1¼" 50mm Finderscope **$59.50**, right-angle	**$59.50**
1¼" straight-thru 80mm SUPER-FINDER	**$179.50**
1¼" right-angle 80mm SUPER-FINDER	**$189.50**
1¼" right-angle version, w/star diagonal	**$229.50**
25mm Cross-hair 1¼" eyepiece (12X)	**$49**
Large mounting rings for 80mm Finder	**$55**
1¼" Star Diagonal **$49**, Mounting Brackets,	**$39.50**
1¼" 45° diagonal for correct left-right views	**$52.44**

LOTS OF ADAPTERS

2" adapter for C-8, Meade 2080, etc.	**$26.00**
2" adapter for C-80, C-100 refractor	**$39.50**
2" adapter for C-70, C-80F, C-100F fluorite	**$39.50**
2" adapter for C-6, Comet Catcher, Meade 312	**$30.00**

EXTENSION TUBES

1" long 1¼" OD thread-in extension	**12.00**
2½" long extension (holds 1¼" filters)	**16.00**
4½" long extension for 1¼" eyepieces	**$25.00**
3" long extension for 2" eyepieces*	**$26.00**
2" long extension for 2" eyepieces*	**$26.00**

VIEWING ADAPTERS

2"/1¼" reducing bushing,threaded 48mm*	**$20.00**
2"/T-thread adapter, threaded 48mm*	**$25.00**
T-thread/1¼" adapter	**$25.00**
F/10 2" or 1¼" eyepiece viewing adapter for Giant Easy-Guider	**$39.50**
Low profile star diagonal eyepiece holder	**$16.00**
Meade 2" Diagonal/Giant Easy-Guider	**$39.50**

**Threaded to hold 48mm filters.*

LUMICON — WORLD CENTER FOR ASTROPHOTOGRAPHY

WHAT DO YOU NEED?

A. For Lunar and Planetary Photography:
1. Basic camera adapter or tele-extender, **$32**
2. Camera T-ring (state brand), **$15**

B. For Piggyback Photography:
1. Cable release, **$10** and piggyback mount, **$59.50**
2. Illuminated reticle, pulsed, wireless **$109.50**
3. 48mm DEEP-SKY filter for lens, **$119.50**

C. For Prime-Focus Photography:
1. Everything for piggyback photography
2. LUMICON EASY-GUIDER, **$170-$395**
3. Dual-axis drive corrector, **$249-$299**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All three types of LUMICON® EASY-GUIDER (off-axis guider/Rich-Field Viewer) offer these unique features: (Patent #4448500)

- **Spectacular unvignetted Rich-Field Viewing with both 1¼'' and 2'' eyepieces***.
- ½'' radial adjustment and full 360° rotation make guide-stars 5 times easier to find.
- Large prism for **bright** guide-stars
- Large aperture 48mm filter compartment
- 360° camera rotation composes pictures
- Extra large achromatic focal reducing lens yields **3X shorter exposures** and edge-to-edge pinpoint star images.*

**Giant and Cassegrain EASY-GUIDERS*

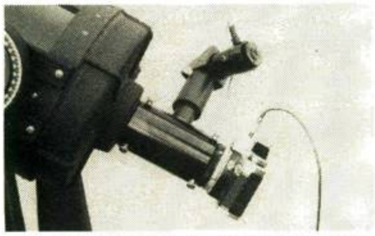
GIANT EASY-GUIDER™ FOR C-11, C-14, M-2120

Fits both Celestron-11 and -14 and the 10'' Meade 2120. 80mm telecompressor lens yields both edge-to-edge illumination and pinpoint star images at f/6. Totally unvignetted! **Superb Rich-Field Viewing!** F-ratio adjustable f/4-f/11.

Giant EASY-GUIDER Rich-Field Viewer with 80mm lens (state camera brand)(add **$29** for Prem. 50) **$395**
Giant Easy-Guider w/o lens (f/6 SCT's) **$295**
Giant Rich-Field Viewer with 80mm lens ... **$250**
12mm illuminated reticle, pulsed, wireless . **$109.50**
Adapter for Hasselblad **$295;** for Mamiya 645 **$149**
Adapter for Pentax 6X7 **$129;** for Bronica SQA **$175**
Adapter for Pentax 645 medium format **$149**

CASSEGRAIN EASY-GUIDER™ FOR C-8, MEADE 2080

Fits Celestron-8 and Meade 2080. Includes 2'' lens for **both** Rich-Field Viewing and photography at f/6. 3X more stars, 3X shorter exposures! **No added vignetting!** Adjustable f/4-f/10. For Meade 2080/LX5/LX6, Premier 50 add $29 for a 1¼'' prism diagonal.



Unmatched Rich-Field Viewing! Add $29 for LX5.
Cassegrain EASY-GUIDER (specify camera) . **$249**
Adapter for Mamiya 645 **$98,** for Hasselblad **$225**
For Pentax 6X7 **$129;** Pentax 645 **$139;** Bronica SQA **$175**
12mm illuminated reticle, pulsed, wireless . **$109.50**
Rich-Field viewing adapter **$20**
Cassegrain Rich-Field Viewer with 51mm lens **$140**
(Photography accessories can be added later for $109)

All foreign orders add 8% ($10.00 minimum).
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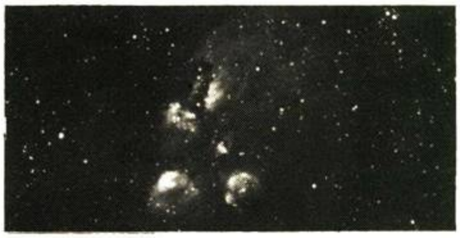
ASTROPHOTO OF THE MONTH



NGC 6334 in Scorplus. Photo by Chuck Vaughn using a 300mm f/4.5 telephoto and LUMICON H-alpha Pass Filter, 30 minutes exposure using LUMICON hypered 2415 film. This nebula is seen best visually with either a LUMICON UHC or Oxygen-III filter.

4X BRIGHTER, BETTER FOCUS w/INTENSCREEN™ PLUS

Olympus OM-1 to OM-4	**$74.95**	Canon EOS 620,-650, RT	**$74.95**
Nikon FE, FE2, FM2, FA, 8008	**$74.95**	Hasselblad 500C, 500EL	**$142.50**
Nikon F, F2, F3 in frame	**$112.50**	Hasselblad 500C/M, EL/M	**$162.50**
Contax RTS II	**$74.95**	Mamiya 645, RB-67	**$142.50**
Pentax LX	**$74.95**	Pentax 6X7, 645	**$133.50**
Leica R4, R5, R6	**$74.95**	Bronica ETR, ETRS	**$142.50**
Canon EOS-1	**$84.95**	Bronica SQ, SQA, GS-1	**$133.50**

Illuminated Reticle Eyepiece

NEW! PULSED ILLUMINATOR

WIRELESS PULSED

$109.50

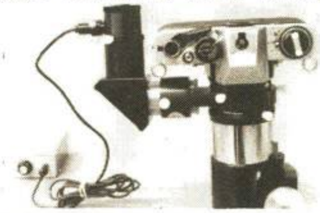
Pulsed Illuminator Alone - $49.50

Essential for astrophotography. Lumicon 12mm illuminated reticle eyepiece has dual crosslines and pulsed red L.E.D. illumination for long life. Includes level control wireless power supply.

NEWTONIAN EASY-GUIDER™

Only ½'' thick (1¼'' version) or ⅞'' thick (2'' version)

Installs in seconds into 1¼'' or 2'' focusing mounts. Full 1-7/8'' clear aperture.



Newtonian EASY-GUIDER (specify camera type & telescope focuser, 1¼'' or 2'') **$189.50**
Guider for Mamiya 645 **$199,** for Hasselblad **$409**
For Pentax 645 **$139;** Pentax 6X7 **$129;** Bronica SQA **$175**
3X Relay Diagonal **$94.50**
12mm illum. reticle eyepiece, pulsed, wireless . **$109.50**
48mm DEEP-SKY Filter ($119.50) .... add **$99.95**

DIGITAL DRIVE CORRECTOR

Lumicon Digital Dual-Axis Drive Corrector
Allows fine corrections in right ascension and declination for astrophotography. Compact control allows "one-hand" operation. Also permits field use of your telescope off a 12V car battery. High performance features are:

- Quartz crystal digital frequency generation
- Switchable lunar, solar, sidereal rates
- Pulse width modulated variable dec. speed
- 12 VDC or 120 VAC input power equipment
- 48/72 Hz "Low" or 30/90 Hz "High" R.A. correction rate
- Declination polarity reversing switch for equatorial mounts
- Handy red light for map/setting circles

LUMICON DX200 dual-axis digital drive corrector **$249**

NEW BUILT-IN BATTERY

LUMICON DX2BP dual-axis digital drive corrector with built-in rechargeable 5AH battery **$299**

HYPERSENSITIZED FILM

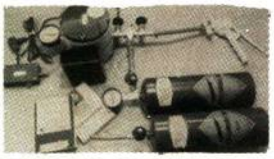
ESSENTIAL FOR GOOD DEEP-SKY ASTROPHOTOS.

NEW KONICA SR-G 3200
Kodak
technical pan film 2415
TP 135-36
Konica
SR1600
Scotch
1000

35mm film specially hypersensitized by LUMICON. B&W: Use 2415 for nebulae; great for galaxies, too. Fastest Color Slides: Use 3M 1000; Fastest Color Prints: Use Konica SR-G 3200. *Deduct 10% for 3 or more rolls.* ***No C.O.D. film orders.***

Film Type (35mm unless marked)	**Expos.**	**Price**
2415, Ultra-fine grain B&W, red sensitive	36	**$11.95**
Konica SR-G 3200, Super fast, Amazing Film!	24	**$13.95**
Kodak Ektar 1000, fast, finer grain	24	**$12.95**
NEW! Konica SR-G 3200, 120 size, hypered	16	**$19.95**
Scotchrome 400, fast color slide film	24	**$12.95**
Fujichrome RD100 fine gr. color slide	24	**$12.95**
Fuji Super HG400 fine gr., high speed neg.		
Konica SR400 120 size medium format	12	**$19.95**
NEW! 6415 (120 size 2415), hypersensitized	16	**$19.95**
5072 (SO-279), makes color slides from negs	36	**$6.95**
Bulk 2415 35mm film, unsensitized	1800	**$59.95**
4415 (4X5'' 2415) 7 mil thick sheets, unsens.	25	**$31.95**
D-19 B&W developer for 2415 & III a-J	1 gal	**$7.95**

FILM HYPERSENSITIZATION KIT †



†Patent #4473636

MODEL 1200 HYPER-KIT™

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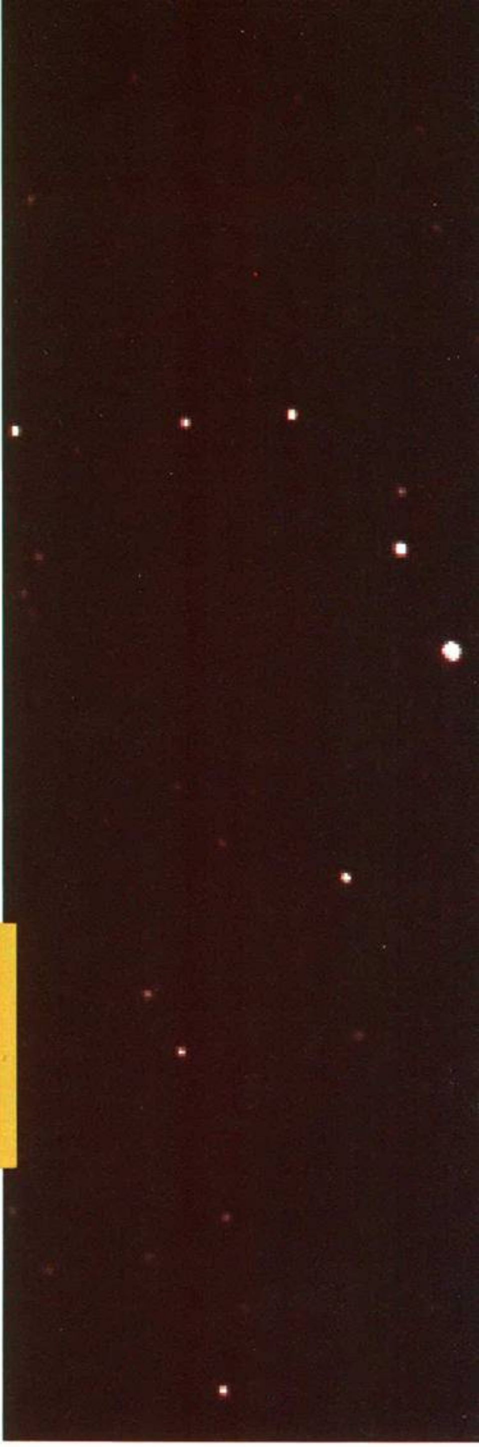
Working in the Digital Darkroom

Three powerful image enhancement routines can spice up or pull subtle details out of astroslides and negatives.

by Richard Berry



IF IT'S FAINT AND SUBTLE the digital darkroom can pull it from the recesses of your film's emulsion. On the original photo, the Helix Nebula's faint wreath-like appearance was lost; in this enhanced version, there's no doubt as to its nature.

Take a picture, any picture, in your collection of astrophotography. Wouldn't it be great to coax out of that picture any faint detail or eyepopping color, all from the comfort of an easy chair? Well, pull up a seat! Today's home computers can team up with image-processing software in a "digital darkroom" to wring out almost any photographic information that might be lurking in your current stash of astrophotos.

Last month "Bring on the Photo CD Revolution!" explored how to take the first steps into the digital darkroom, namely by transferring astrophotos from negatives and slides to Photo CD, Kodak's version of a CD-ROM. Locked into those pictures is loads of information that to print in a conventional darkroom would require an immense amount of patience and money (for chemistry, paper and the right darkroom equipment). Well, forget the stinky chemistry, the lost hours, and lack of a family life. The digital darkroom yields great results consistently, using some powerful routines afforded through image-processing software such as PhotoStyler or PhotoShop.

Using these programs, three routines can be run on pictures stored on a Photo CD. The most basic routine, the Stretch, makes an image appear clean and snappy, alive with vibrant colors against a dark sky. It works wonders on flat, dull astrophotographs. The Pump routine shows the faintest possible nebular detail, leaving stars and the bright parts of nebulae pure white. It is equivalent to printing on high-contrast photographic paper. Finally, the Wow! process deals with removing sky glow, vignetting, and flaws due to uneven processing. Although the Wow! process doesn't work equally well on every image, it is capable of transforming a wide variety of ordinary-looking astrophotos into dramatic views of the universe. Upon trying these three routines, you will be amazed to discover how much information lies hidden in ordinary celestial photographs, and how easily it can be retrieved with digital image-processing.

While this article uses PhotoStyler and PhotoShop as vehicles to convey how to perform these processes, by no means are they the only image-processing software on the market. Stretch, Pump, and Wow! involve image-processing concepts that are relatively universal, easily done on the image-processing program of your choice, provided you're well-versed with that particular program's features and capabilities.

Before processing images from a Photo CD, a brief admonition about biting off more than your computer can chew. A Photo CD provides a choice of image sizes, from the minute Wallet, to the multi-megabyte Poster size. Because the computational demands of image-processing can rapidly overwhelm a personal computer, it's easy to end up watching the hourglass cursor (or for Mac *users, the wristwatch), quite literally* for hours. Learn image-processing using the standard size images, with a

Richard Berry

mere 1.2 megabytes per image. A computer will handle these lightweights far faster than it can handle the big files, and the hard disk won't fill with processed images quite as quickly. Once you get the hang of using Photo CD images, you may want to work a few images in the "large" size, but remember these weigh in at a hefty 4.6 megabytes each. On a system with 8 megabytes of RAM, you'll be up all night. The only time you'll probably ever need to play with the gorilla-sized Poster images is for some super-sharp Tech Pan shot, when the 18.4-megabytes per image is justified.

Enough ground rules; it's time to get introduced to some tools.

Mad for Histograms

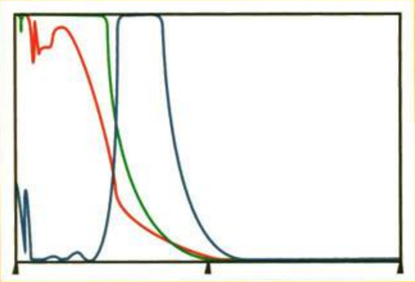
If image-processing software is a box of tools — saws, hammers, stapler — then the Histogram function is a ruler or measuring tape. In carpentry there's an old saying: Measure twice, cut once. Before being processed, you'll need to measure the image. But what exactly does this measuring tool measure?

Imagine that the image on a computer screen rather than being made up of pixels could instead be seen as a mosaic of ceramic tiles that have different shades of gray. If all these tiles were dumped into a box and then stacked into piles according to their grayness, you would

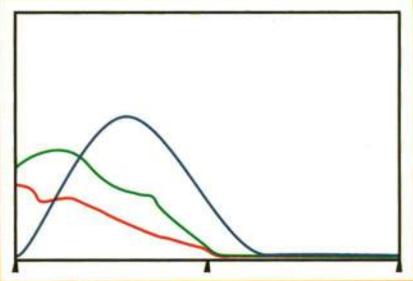
ASTRONOMY: Chris Becker

STRETCH

COMET HALLEY SWEEPS through southern Scorpius in this April 5, 1986 photo. Because of sky glow or color shift in the film, the picture's overall cast is bluish, and star clouds that are normally easy to see look dull and washed out.



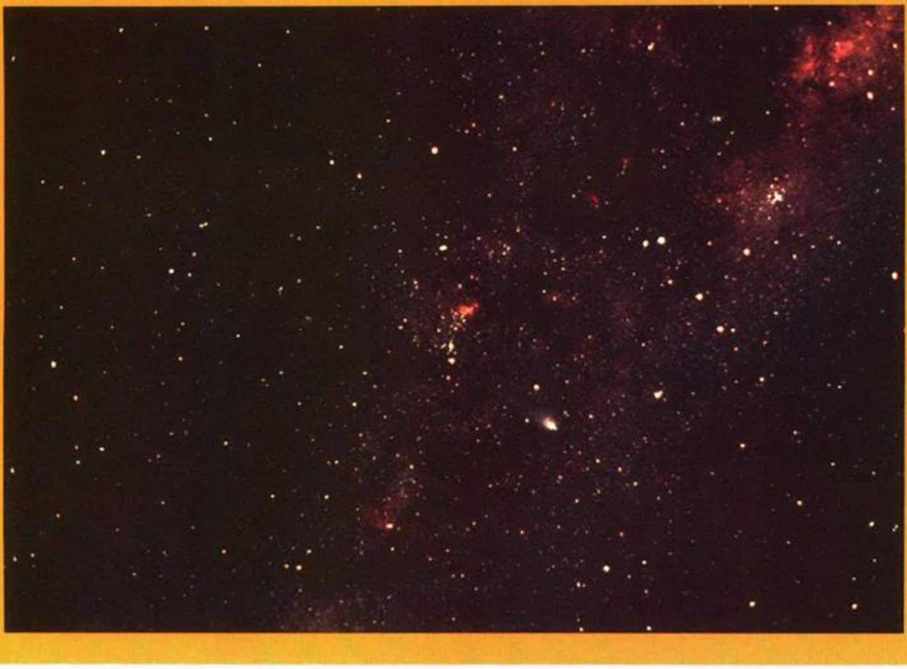
BY ANALYZING the histograms for each color channel, it's easy to see why the picture looks so bluish. Notice the blue channel's peak is shifted to the right, where the color is most intense, while the red and green channels are crowded into the low intensity region of their respective histograms.



USING RANGES OBTAINED from the original image's histograms, we've tried to "standardize" the intensity range for all colors. Note that the adjusted image's histograms, especially for red and green, cover a wider intensity range.

APPLYING THESE NEW RANGES yields what looks like a totally new picture. The sky is blacker and has more contrast. Emission nebulae and star clouds scattered along the plane of the Milky Way come alive with renewed vibrance. Comet Halley doesn't look too bad either.

David Healy



have a histogram, a plot of the number of tiles within each level of brightness. In image-processing, the histogram shows at a glance how the brightness (or intensity) values in an image are distributed. If a picture is a uniform gray, then all the pixels will lie in a narrow region in the middle of the histogram. But if a picture has good contrast, the pixel values will be spread from one end of the graph to the other, from a low of 0 to a high of 255, with a mild concentration somewhere near the middle of the range, usually between 80 and 180.

For color images stored on a Photo CD, the situation is a little more complex. In the computer, colors are made by combining three monochrome images or channels: red, green, and blue. Color images of this type are called RGB images. A histogram can be generated for each color channel which shows values assigned to pixels that determine color intensity. If a color image's red, green, and blue pixel values are the same, the picture's predominant color will be gray. If one color, say green, predominates, the histogram for the green channel will be shifted toward higher intensity values, while the histograms for blue and red overlap in a common but lower intensity region. With the help of these red, green, and blue histograms, some image-processing routines can be applied, the first of which is coined the Stretch.

One . . . Two . . . Stretch

Astrophotos look flat and lusterless when crucial image information occupies only part of the range between the lowest pixel intensity (0 in histogram language) and the highest (255). There's nothing wrong with this because it's probably a pretty accurate record of the light that actually fell on the film. Even the darkest skies on Earth are not completely black, and many faint nebulae and galaxies are washed out by sky glow. Nonetheless, astronomical images look best when at least some of the pixels are pure white and a reasonable number of pixels are distributed across the full 0-to-255 range of intensity values. The Stretch routine's primary goal is to spread out the range of pixel intensities for each of your image's color channels. This is done by analyzing the histograms of each color channel (red, green, and blue) that compose the color picture. So pull out the image-processing tape measure, the histogram, and let's get started.

To access these histograms, use the Image Histogram function found in PhotoStyler or PhotoShop. A histogram will appear for the picture's "RGB" channel, which shows the combined pixel intensity ranges for all colors. It looks like a bumpy graph, and conveys how many pixels in the image have intensity values between 0 and 255. For this work you'll need to see separate histograms for each of the image's red, green, and blue channels. A dialogue box displayed near the histogram graph should allow for the selection of different channels. With the first color channel histogram displayed, you can collect two important numbers.

Run the pointer/cursor left to right along the bottom of the histogram, between the 0 (lowest) and 255 (highest) intensity values. As this is done, corresponding information about what percentage of the pixels at or below certain intensity values should be displayed elsewhere in the window. Slowly move the cursor horizontally along the histogram's base until the percentage readout reads as close to 1 percent as possible. Write down the intensity value at this point; only one percent of the total number of this color channel's pixels are at, or below, this intensity value. Continue moving the cursor to the right, until the readout reads as close to 99 percent as possible, again noting the intensity value. Ninety-nine percent of this color's pixels are at, or below, this intensity value. Subtract the low intensity value from the high to get the intensity range most of this color's pixels lie in. Repeat these steps for the other two color channels, noting the lowest and highest intensities as well as their ranges.

Take a look at the ranges calculated for each color. The highest range for all three colors (call it the perfect range) is the one of interest from here on out. Take this greatest range and add it to the low-intensity values obtained for each color channel. This will yield a new set of high-intensity values, which are going to be used to complete the image-processing. If a universal range added to a low-intensity value yields an adjusted high-intensity value over 255, ignore it and use 255. Now you are ready to apply these new numbers to the image.

Select the Image Adjust Levels function (PhotoShop) or Image Tune Tonal/Correction function (PhotoStyler) and set the high-intensity values for each color to the values calculated. Then press Preview. The image will change dramatically.

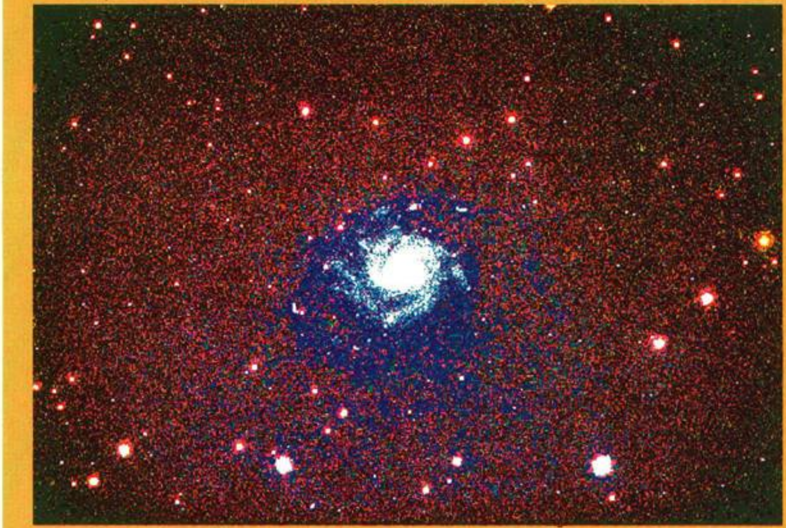
The sky background will become dark gray instead of a washed-out shade of brown, blue, or green. The subject should appear clean and snappy and show bright colors, and the brightest stars will shine pure white. Overall, though, the image may look too light or too dark. To adjust overall brightness, use what's called the gamma control. In PhotoStyler, the gamma control is a slider bar that displays a numeric value at one end; in PhotoShop, it's the triangular slider in the middle of the RGB histogram. In either case, if the image looks too dark, set the control to a value greater than 1; if the image looks too light, set the control to a value below 1. The Preview button can be pressed each time to see how changing the gamma value affects overall picture brightness.

PUMP

THE SPIRAL GALAXY M101 barely shows its core and brighter arms. How far out into the picture does the galaxy's spiral structure extend? To see what latent detail is present, let's run the Pump routine.

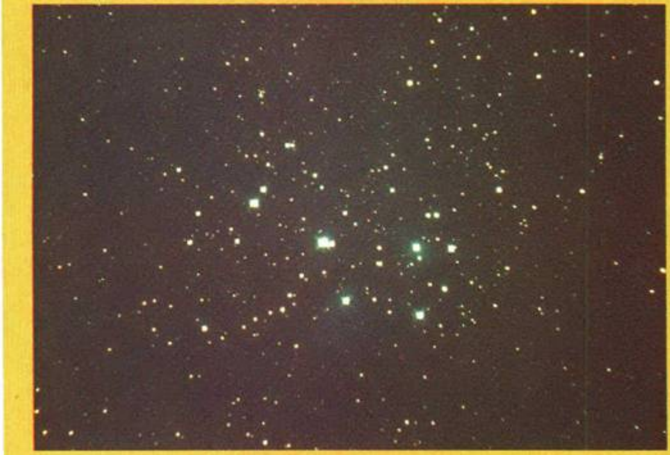
TO BOOST SUBTLE DETAIL take a tiny chunk of dark, starless sky near the center of the original photo's frame and analyze its red, blue and green histograms.

Jack Newton

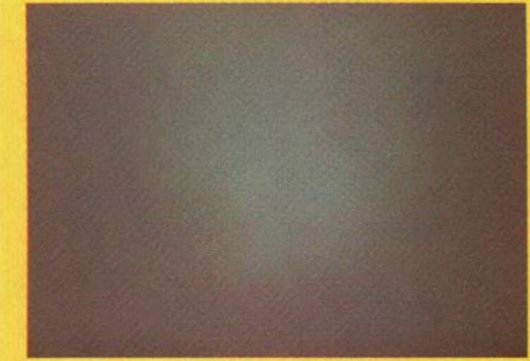


WITH DATA OBTAINED from that tiny piece of the sky, apply new intensity ranges to the original picture. The result: A grainy, "noisy" — and very colorful — view of M101 that shows spiral detail does indeed extend far from the brighter portions of the galaxy.

WOW !

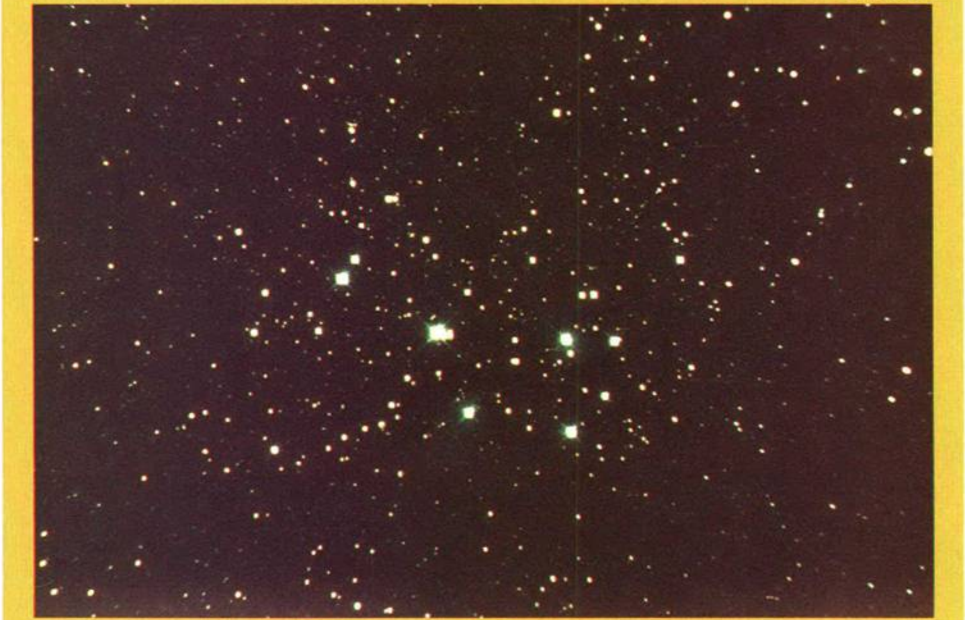


THIS WIDE-FIELD VIEW of open cluster M45, the Pleiades, suffers from vignetting (the edges of the picture get darker) and a greenish cast due to a color shift in the film or sky glow. To deal with these problems, let's apply the Wow! routine.



ALL THE STARS are filtered out, leaving only a greenish sky and vignetting effects. All defects in this filtered frame can be subtracted electronically from the original picture.

Hal Jandorf



SUBTRACTING THE FILTERED frame from the original image works wonders. Notice the sky is a uniform black, no more sky glow or light fall-off away from the center of the photo. The Pleiades and its attendant nebulosity also show more definition.

Once you obtain the desired brightness, just hit Save and a copy of your first image enhancement will be permanent.

Pump It Up

Where Stretch tries to make a picture look pretty, the second enhancement technique, Pump, takes on the problem of pulling faint, wispy detail from astrophotos. Just how much of that Dumbbell or Veil Nebula photo has undiscovered, delicate tendrils of gas and/or dust? "Pushing the envelope" to glean these details, the Pump, extracts the most nebulosity from pictures. This process works equally well for color or black and white images, so those hypered Tech Pan negatives you shot a few years back can be pumped as easily as a slide or color negative.

Load the image and inspect it, locating a small region of background sky near the center of the frame with no stars or nebulosity in it, perhaps a spot about 16 pixels square (the exact size is not critical). With the Select tool, mark the region, copy it, and then paste it back to the desktop as a new image.

Select the Image Histogram function and analyze the red, green, and blue histograms for the sky image. As you did for the Stretch, write down the highest and lowest intensity values below which, respectively, 99 percent and 1 percent of the pixels lie. There are no calculations here as there were for the Stretch.

Return to the original image. Select PhotoStyler's Image Tune Tonal/Correction or PhotoShop's Image Adjust Levels function, and plug in the intensity numbers derived from the tiny-piece-of-the-sky analysis. Press Preview and watch what happens: The sky becomes a psychedelic patchwork of multi-colored pixels! The bright parts of the nebula will appear pure white, and if there is any vignetting in your image, the edges will be too dark. However, if there is any nebulosity in the sky, you will see it clearly. At this stage, the overall image will probably be too bright. Darken it by setting the gamma slider to a value lower than 1; try several values between 0.3 and 0.8 and Preview them. Colors in the image will appear stronger and darker when this is done. When the image looks good, click on the Okay button to store a permanent version of your final adjustment.

"Pumping" works best with extremely faint nebulae, bringing out faint haloes and streamers that would be difficult to print in a darkroom using conventional wet-chemical techniques. In the digital darkroom, all it takes is a few clicks of the mouse. Furthermore, this process automatically creates an image with intensely colored nebulae on a neutral gray background. Unfortunately, "pumping" does render stars and bright nebulae pure white and reveals image flaws such as vignetting and non-uniform processing with painful clarity. On the other hand nebular details are shown that conventional printing would barely reveal without a ton of work.

Get Ready for Wow!

Both the Stretch and the Pump processes are limited by the non-uniformity in the original photograph. If too little light has fallen on the corners of the picture, they will appear dark (vignetting). If the film has been processed in a small tank, processing streaks will probably be visible along one or both edges of the film. Wouldn't it be great if photographic images could be calibrated to correct for these flaws? With the Wow! process they can.

Think of an image flawed by vignetting and processing flaws as the sum of two separate components: the ideal image of a celestial object plus the unwanted, flawed background. Suppose that the ideal image could be erased from the original image, leaving only the flawed background. If you could accomplish this erasure and then subtract the flawed from the original image, the ideal image would remain. This is the gist of the Wow! routine.

To work properly, the Wow! process needs celestial objects whose borders are reasonably well defined; that is, they should have edges that are easy to locate. A fairly bright deep-sky object that fills the middle one-third of a picture (say a well defined spiral galaxy) is ideal because its edges can be easily distinguished from the sky around it.

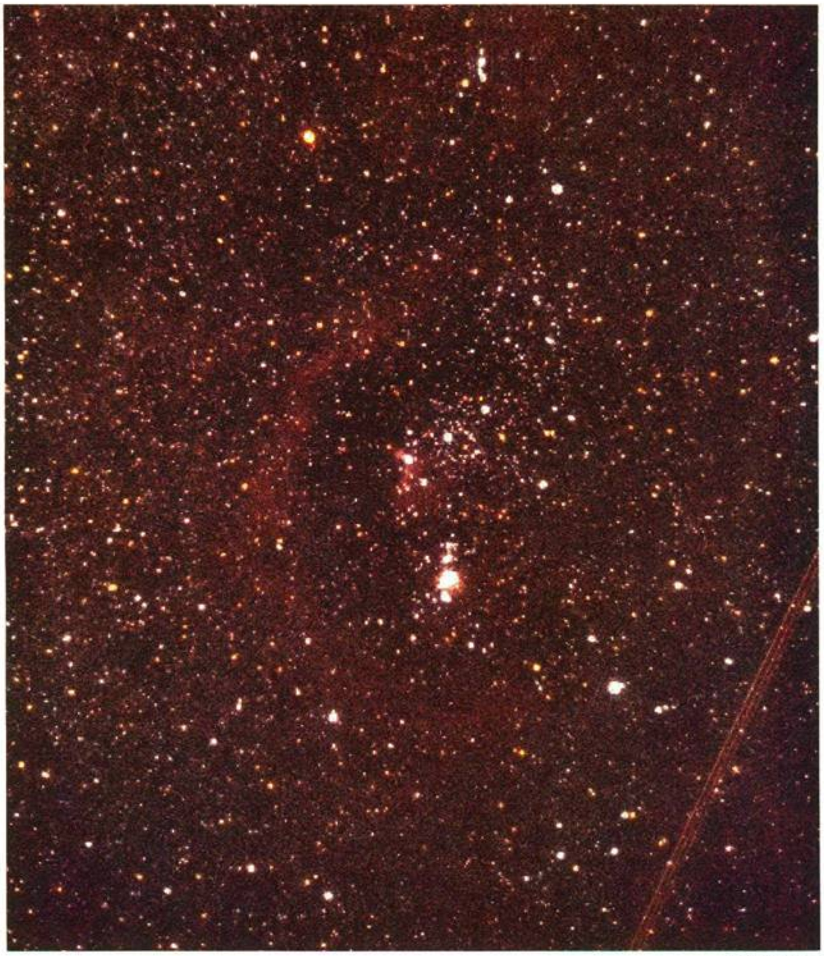
In PhotoStyler, start by making a duplicate of the original image. Then use the Effects Soften Median function to remove the bright stars in the copy. Set the radius to a large value —16 to 24 pixels — and watch what happens. The stars disappear. This function replaces bright pixels (stars) with the most common (median) pixel value that surrounds each star, which is sky background. Save the median-filtered image in case another attempt needs to be made. Take the results to the next step: erasing the deep-sky object.

By now the deep-sky object should appear as a mushy blob in the center of the field. Select the blob with the Magic Wand tool and, using the Paint Bucket tool, fill the blob with the sky color immediately surrounding the blob. Use the Effects Soften Gaussian Blur function set to a large radius, say 12 pixels, to blur away any of the object's remaining sharp edges. Save this image in case things go wrong and then proceed to the final step.

This final step uses PhotoStyler's Image Calculate function to subtract the flawed image that's been created from the original image. The resulting new image will look almost black. Carry out a Stretch on this frame and be prepared to say "Wow!" The picture should show the deep-sky object shining jewel-like on a velvet-black background. There may be some experimentation involved with the Wow! process before getting it right, but when properly applied, the results are awesome.

In PhotoShop, the Wow! routine is identical but the functions have different names. Copy the original image and paste it into a new image to make the duplicate. Use the Filter Noise Median function to remove the stars and the Magic Wand and Paint Bucket to wipe away the object. Smooth the copy with the Filter Blur Gaussian function and use the Image Calculate Subtract function to carry out the subtraction. Do a Stretch and sit back to admire the handiwork.

So there you have it: Stretch, Pump, and Wow! While they are powerful tools in the digital darkroom, these techniques should be seen as starting points, routines you can experiment with as you process images to your heart's content. The rules are yours and, quite literally, the sky's the limit. □



Richard Berry

BARNARD'S LOOP WRAPS itself through the familiar stars of Orion the Hunter in this digitally enhanced photo. Image-processing also brought out a less desirable feature: an airplane trail through the lower right.

Richard Berry has applied CCD imaging and image-processing to astrophotography, his long-time hobby. Berry's latest book is The CCD Camera Cookbook, *which describes how to build a 378x242-pixel CCD camera.*

Charles Manion

A STORMY PERSEID FORECAST?

Dozens of meteors per hour will flash overhead during peak hours of this month's Perseid meteor shower. And there's a chance the shower may contain a rare meteor "storm."

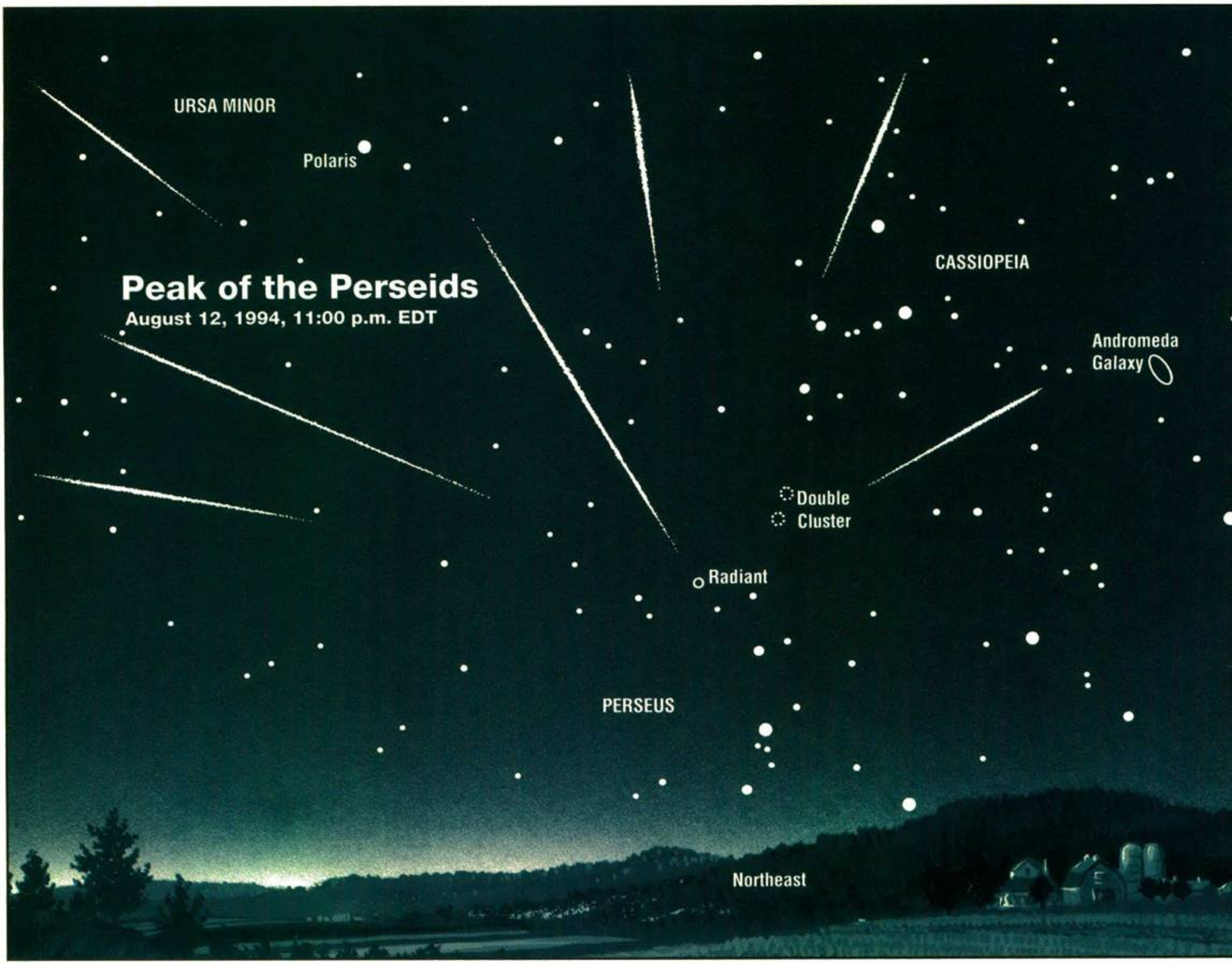
by Philip M. Bagnall

Dust off the lawn chairs, unroll the sleeping bags, and stock up on bug spray — the year's best meteor shower peaks on the night of August 11/12. Observers can hope to see as many as 100 streaks across the sky per hour. As with last year's shower, astronomers feel the Perseids may turn in an impressive performance this August. Why? Because the shower's progenitor comet, Swift-Tuttle, returned to the inner solar system in 1992, presumably leaving behind a dense cloud of debris to produce a "storm" of meteors in Earth's atmosphere.

Yeah, and Elvis works in a convenience store in Minot, North Dakota, right? The astronomical soothsayers predicted a possible meteor storm for last year's Perseid shower and none occurred. The event was a good one, the Moon was out of the way, and many bright fireballs raced down the spine of the Milky Way, leaving observers with a greatly satisfying year. But it was no storm.

Will the August Sky Storm?

If the storm failed to come in 1993, astronomers reckon, perhaps it will arrive in 1994. So suggest Iwan Williams and Zidian Wu of Queen Mary and Westfield College in London. They base their prediction on a detailed study of the 1862 apparition of Comet Swift-Tuttle, the comet's last appearance before its recent return. Williams and Wu believe that in the last few years Earth began to encounter clouds of dust ejected by the comet in the last century. They contend that this accounts for the slow but steady increase in Perseid activity observers have reported over the last few seasons. Because of their study, they believe that Earth



will pass through the thickest cloud of dust from Swift-Tuttle this month.

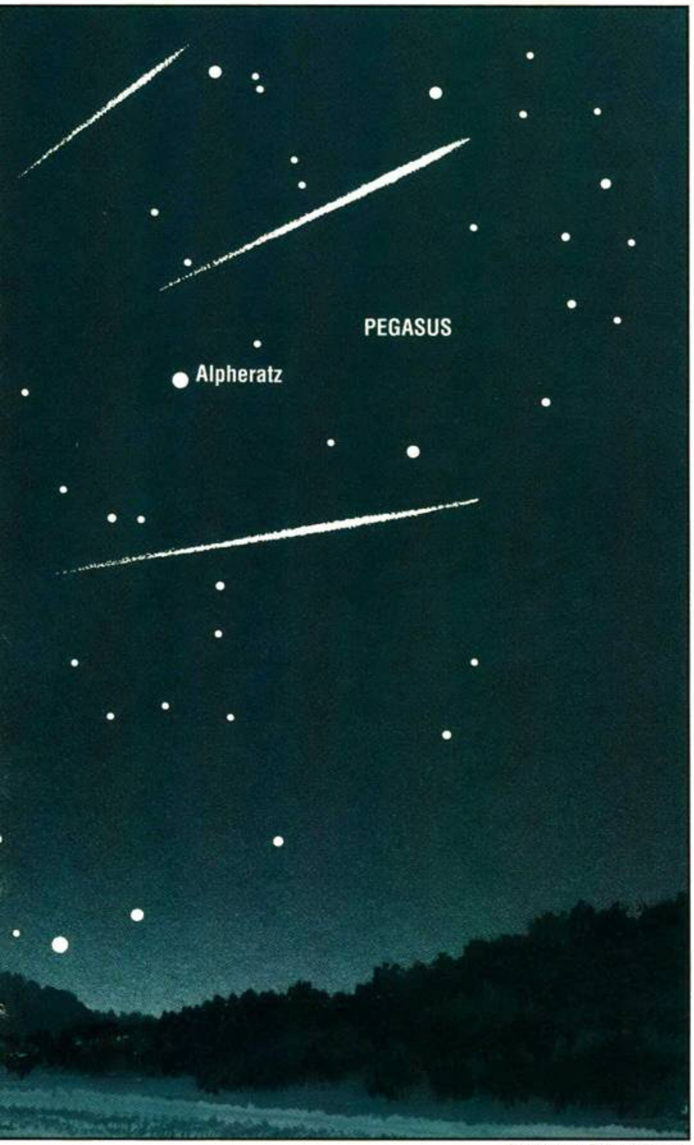
If Williams and Wu are correct, then we may well be in for a spectacular display this year (honest!). And fortunately conditions are going to be almost as favorable as they were last year. At the time of the shower's peak, early in the day on August 12, the Moon will be two days shy of First Quarter, meaning it will set in the late evening before the prime hours for meteor observing. Because the peak occurs in the early evening you may wish to begin observing as soon as the sky is dark enough. If a storm should occur, you may see some bright meteors even under twilight conditions. The number of meteors should increase after midnight, however, when Earth's nightside turns directly into the cloud of meteoric debris and the sky is darker than during the early evening hours.

Keep it in mind that a meteor shower's maximum activity is difficult to pin down. Small numbers of Perseids are normally visible from about July 23 until August 20 but the rates of activity are relatively low during most of this period. Because of the uncertainties of this year's event — which include not only the normal ones about when the peak will occur and whether it will be a meteor storm — you may wish to begin observing as early as possible and watch the sky for as long a period as possible. A storm, if one does occur, may happen one or two days on either side of the predicted maximum. What happens during the rest of the period is anyone's guess.

Regardless of which evening you choose to venture out, you need to know where to look. The best way to observe any meteor shower is simply to lie back and look up with your eyes alone. At maximum the radiant, the position from which the meteors appear to come, is at a point near the star Eta (η) Persei at R.A. 3h6m, Dec. +58°. Following peak activity the radiant will appear to drift slightly, each day moving eastward by 1.35° and northward by 0.12°. However, more than a single radiant may be active, and different radiants may be active on different nights. The radiant is an optical illusion: Because the meteors enter Earth's atmosphere with parallel trajectories, they appear to radiate from this spot. But the bottom line is that by lying back and looking straight up you'll see the most meteors possible.

Watching the Perseids in Style

Aside from that simple advice, you may wish to bring along a number of accessories to make meteor



ASTRONOMY: Robert Wegner

watching comfortable. A lawn chair or chaise longue *will* preserve the integrity of your neck, and a sleeping bag placed on top of it will keep you warm as the summer air chills in the early morning. Dress warmly, too: A hat and gloves will keep you toasty. Bring along a boom box to fill the air with soothing sounds (no Guns 'N Roses, please) and perhaps some food and a warm mug of coffee, tea, or cocoa. You'll probably need a red flashlight to see your way around without ruining your dark adaption. You may also wish to bring a pair of binoculars to spot trains — the occasional glowing trails left in the wake of bright meteors. Either an accurate watch and note paper or a star chart (that allows plotting the paths of bright meteors) will help with recording the times and rates of the meteors.

Bright and faint meteors are visible away from city lights. Drive to a spot where city lights are placed away from the radiant. From a dark site you may see that some of the brightest meteors break apart into several pieces. Try to estimate the magnitudes of bright meteors by comparing them to bright stars located nearby. This isn't easy but gets easier after viewing a number of showers. Should you come away with a record of the meteors you observed, their times, brightnesses, and locations, you may wish to send a copy to the American Meteor Society (Dept. of Physics and Astronomy, SUNY, Geneseo, NY 14454) and the International Meteor Organization (Physics Dept., University of Western Ontario, London, Ontario, N6A 3K7 Canada).

Meteor Observing Accessories

Taking a few items with you to your favorite meteor observing location will make the experience more comfortable and enjoyable. Be sure not to forget any of the following items:

- Sleeping bag or blankets for warmth
- Lawn chair or any comfortable chair
- Thermos of hot coffee, tea, or cocoa
- Red-lensed flashlight
- Star chart to record meteor tracks
- Binoculars to observe trains
- Camera equipment and film
- Bug spray
- Note paper for recording observations
- Boom box for soothing music
- Food

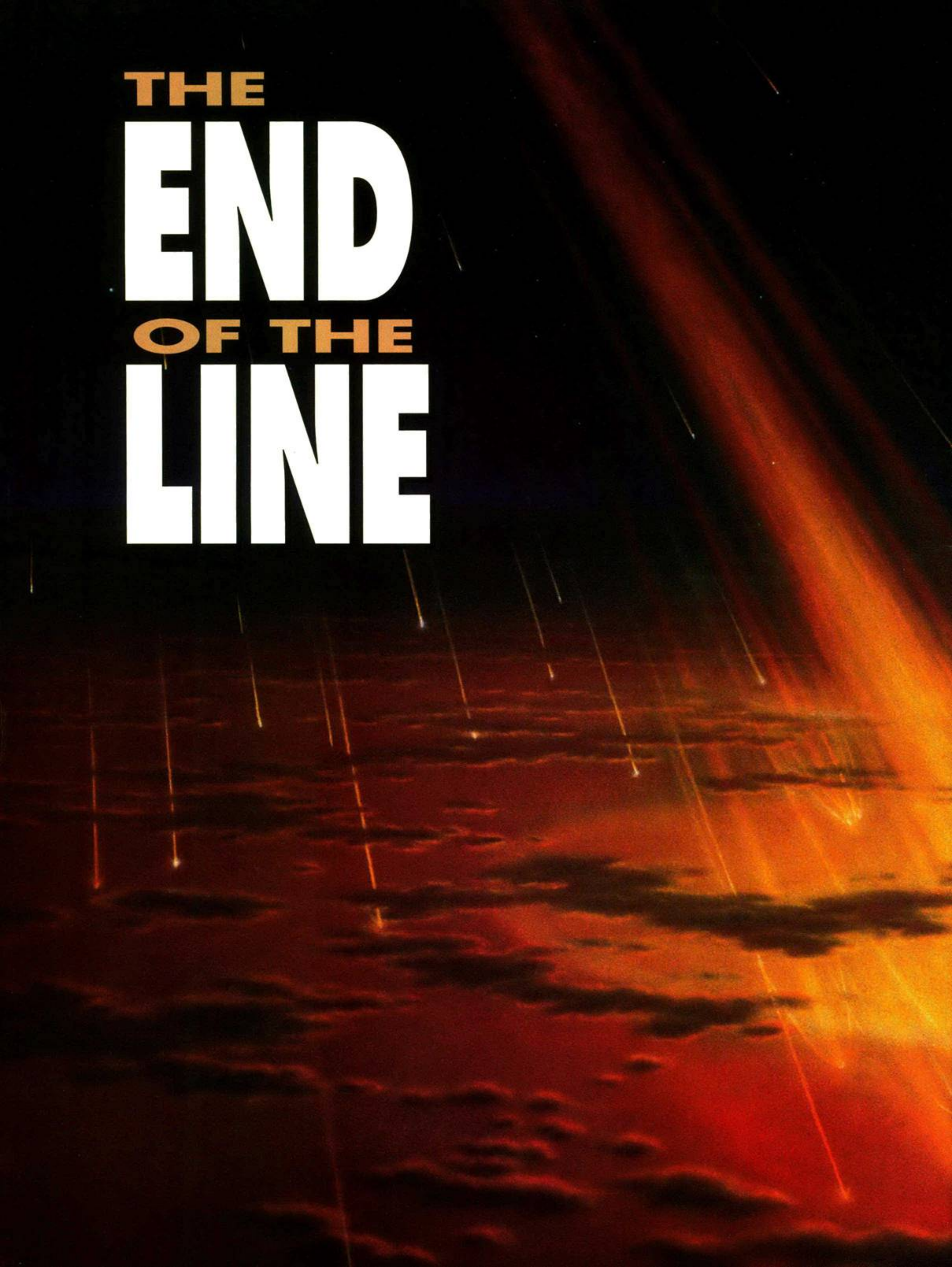
Photographing the Perseids

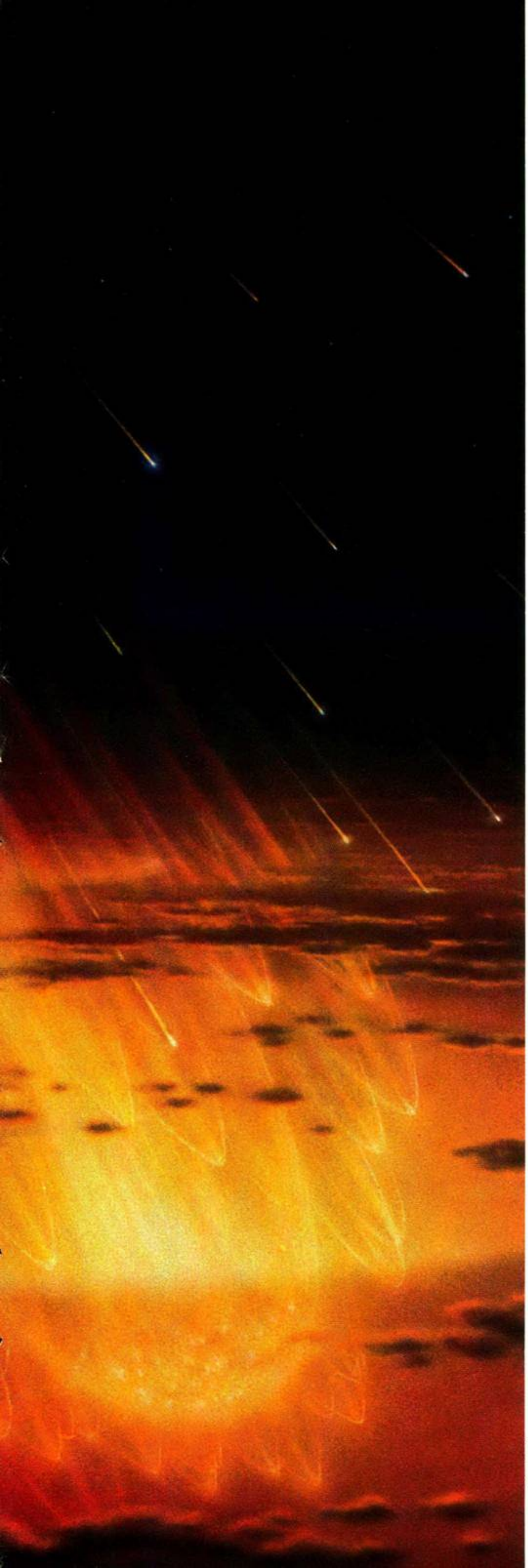
Of course, recording with pencil and paper is not the only way to document the Perseids. You may choose to photograph the shower, which is significantly easier than you might guess. You'll need a 35mm SLR camera with the ability to keep its shutter open for several minutes or longer. (Some 35mm cameras use battery power to hold the shutter open and therefore drain the batteries over a long exposure.) Load your camera with fast film (ISO 200 or greater) and set it on a sturdy tripod. You'll want to open your lens to a fast setting (f/2 or faster) and preferably use a wide angle lens, aiming it above or away from the radiant in the sky — perhaps 45° above the horizon — and focusing at infinity. By opening the shutter and letting the starlight soak into the film for periods of 15 minutes to an hour, you may catch a meteor or two in the field of view. It's really quite straightforward, and you can use color or black and white film. If you're lucky, you'll end up with some nice meteor trails shooting through the arcs made by stars. If you're unlucky you'll get some nice pictures of star trails. If you record any interesting sights from the shower, please send copies of the photos to ASTRONOMY for upcoming editions of Reader Reports.

Whether you photograph the Perseid shower or simply lie back and watch it, this year promises a meteor-packed night or two of skywatching. On the peak evening you could see as many as 100 Perseids per hour — one every 36 seconds on average. And if the storm predicted by Williams and Wu takes place, you may see more than that. ☐

Philip M. Bagnall is president of the Society of Meteoritophiles. He has profiled a number of meteor showers for ASTRONOMY.

THE END OF THE LINE





A remarkable week in the solar system begins on July 16, when the first chunk of Comet Shoemaker–Levy 9 slams into Jupiter. With a little planning, you and your telescope can witness history in the making.

by David J. Eicher

Sentenced to destruction by wandering into Jupiter's gravitational embrace, the fragmented Comet Shoemaker-Levy 9 will meet its doom between July 16 and 22. One by one, its 21 major and thousands of minor pieces will slam into the cloudtops of Jupiter and vaporize with a force of up to 10 trillion tons of TNT. The event was ordained by the comet's capture by Jupiter about a century ago and subsequent fracture in 1992. Only in March 1993 did planetary scientists Gene and Carolyn Shoemaker and David H. Levy discover the comet and enable astronomers to determine its peculiar history.

The event will be the first of its type ever witnessed (see "All Eyes on the Comet Crash," June 1994). Because of this, no one is sure of the visibility of any effects the impacts may cause in the Jovian atmosphere. In fact, no one even knows the amount of energy that will be released because the size of the fragments is not precisely known. Unfortunately for earthbound observers, the impacts will occur on the nightside of the planet, out of direct view. But the planet's rapid rotation will carry the impact zone into view minutes after each strike. The types of phenomena that may be visible will last from seconds to weeks, so it's possible that backyard observers may catch a glimpse of the action.

To have a chance, however, you'll need to get started observing Jupiter early. That means regularly watching the planet under good seeing conditions for at least several nights before the first strike occurs. Any visible effects such as disturbances in the planet's cloudtops will be visible only to keen-eyed observers who can detect the differences in Jovian clouds from the previous day or hours.

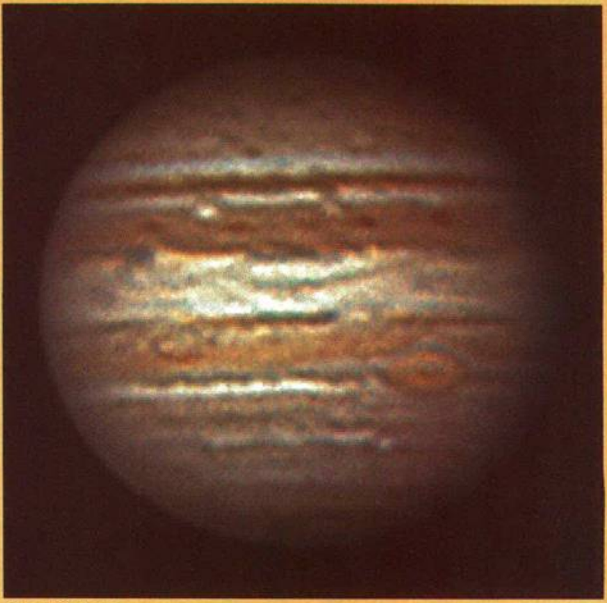
Thankfully, Jupiter stands out like the proverbial sore digit on these evenings. The planet now lies in Virgo and gleams high overhead at sunset on these warm summer evenings and sets around 1 a.m. daylight local time. Finding it is trivial: Jupiter is the second brightest object in the evening sky, after Venus. It lies about 2° northwest of 5th-magnitude Lambda (λ) Virginis. By midmonth the planet shines brilliantly at magnitude –2.1, is 99.1% illuminated by sunlight as viewed from Earth, and measures 38.5" across at its

SWOOSH — BOOM! The first large chunk of Comet Shoemaker-Levy 9 will smash into Jupiter's cloudtops on July 16 at 3:55 p.m. EDT. Detecting the subtle changes in Jupiter's clouds caused by the comet's 21 big impacts means familiarizing yourself with the Jovian cloud features.

Don Davis

GETTING TO KNOW JUPITER

SUBTLE DISTURBANCES IN JUPITER'S CLOUDS may result from the impacts of Comet Shoemaker-Levy 9. Familiarize yourself with the planet's current cloud patterns so you can spot changes in the wake of the impacts. This means observing the planet carefully — particularly the zone between 40° and 50° south latitude — during the first two weeks of July. These high-resolution CCD frames, covering the entire Jovian globe, have north at top and show the planet's cloud configurations in March 1994, so most major features should resemble those shown here.



Donald C. Parker

equator and 36.0" across at its poles. A gulf of 475 million miles separates us from Jupiter, meaning that sunlight reflected off its clouds takes all of 42 minutes and 38 seconds to reach us. The planet is striped by dark and light bands of cloud and peppered with blue festoons, white spots, and areas of tawny brown and gray shading. The planet's cloud patterns also host the solar system's most entrancing storm, the Great Red Spot. Early in July mighty Jupiter will appear like the same familiar planet we see routinely in our telescopes, but for five and a half days it will be a very different place.

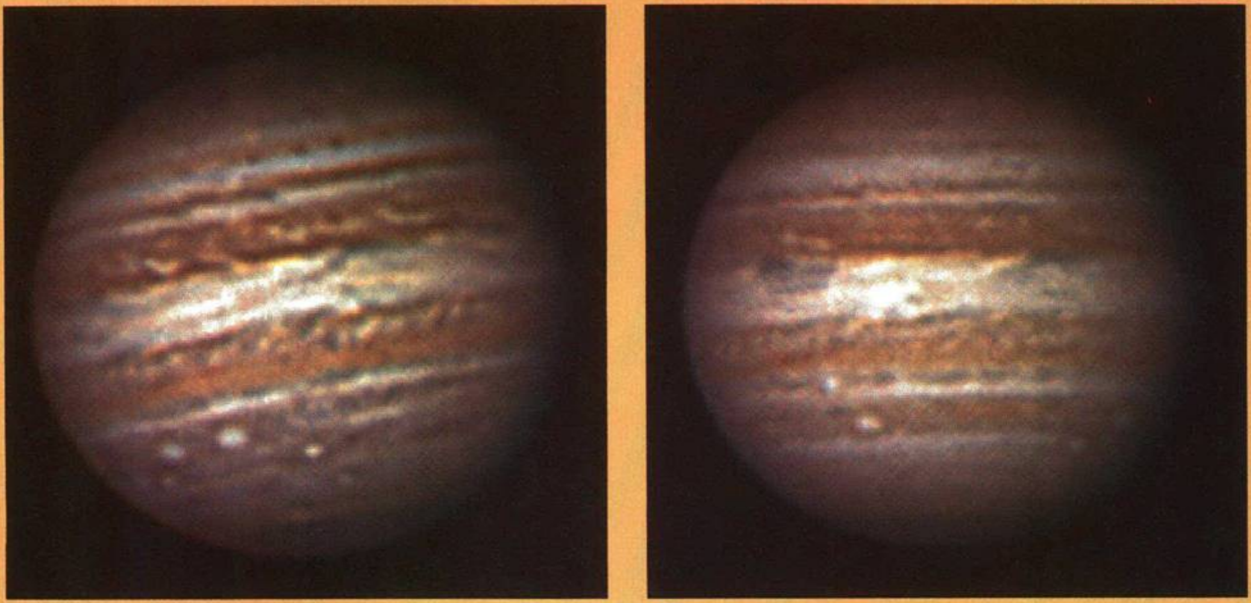
The comet's first major fragment will strike Jupiter at 3:55 p.m. EDT on July 16 — with the First Quarter Moon a mere 3° away — inaugurating a grand experiment in observational astronomy. Astronomers tracking the fragments in anticipation of what may happen have given them letter designations. The first fragment to strike will be A. Only thirteen of the fragments are relatively bright (and presumably large) enough that astronomers have plotted their precise orbits: They are A, E, F, G, H, K, L, N, P, Q (the brightest), R, S, and W. Six others are fainter, so their positions are not as well known: They are B, C, D, T, U, and V. Two fragments, J and M, dissipated last spring, and two others, P and Q, split in two. Astronomers believe the two vanished fragments may have been dense clouds of material rather than solid chunks of ice and rock. The fragments that fragmented further may have had fissures that warmed slightly and caused them to crack apart. So astronomers began tracking 21 fragments last year and now end up tracking 21 — not the same ones, but the same number.

All 21 fragments will speed into the same region in Jupiter's atmosphere — that lying between 40° and 50° south latitude — in machine-gun fashion between the impact of A and the final impact, that of fragment W, at 4:34 a.m. EDT on July 22. The table on page 76 provides the impact times for the other fragments.

As these times suggest, some events offer better viewing than others. The window of opportunity will be rather slight: twilight begins at about 8:30 p.m. local daylight time, the sky is fully dark by about 10:15, and Jupiter sets by about 1 a.m. For North Americans, most of the impacts occur during the day or after Jupiter has set, complicating the visibility of the comet crash aftermath. Further, the planet's rotation period enables seeing the impact zones for about five hours following each impact — after that, the impact area rotates behind Jupiter's western limb (as seen from Earth) until it reappears another five hours hence.

On the East Coast, three impacts, those of B, F, and U, take place with Jupiter in a dark sky, so you can view the effects minutes after they occur as the impact sites rotate into view. Fragment L will impact late in the afternoon of the 19th, meaning the impact site will still be visible as the sky darkens that evening. Seeing the effects of the other fragments will be trickier, however. The crash sites will face Earth again about 10-15 hours and 20-25 hours after the impacts. This means you may be able to see the effects of fragments D and E on the evening of the 17th, C on the evening of the 18th, G and K on the evening of the 19th, P on the evening of the 20th, S on the evening of the 21st, and V on the evening of the 22nd. The effects of fragments A, H, N, Q, R, T, and W will be very difficult to see in the hours following their impact.

But pinning down just what these effects will be is highly speculative, and it's worth observing Jupiter during the whole period to see what happens. To consider the possibilities, astronomers held a workshop at the



University of Maryland in January 1994 and compiled a document suggesting five broad types of activity of various timescales in the wake of each impact.

Summarizing the results of this meeting, Reta Beebe of the University of New Mexico provided a table of phenomena at the American Astronomical Society meeting in Washington last January. The initial fireball from the fragment's entrance into and explosion in the Jovian atmosphere may last less than one to three minutes. A plume of ejecta falling back into the Jovian atmosphere could last up to three hours. Seismic waves created from the explosive shock may be sustained for several hours. Atmospheric waves could last several days. Finally, atmospheric effects such as cloud disturbances could live on for a period of weeks after each strike. Apart from the effects on Jupiter, you can look for a possible momentary brightening, a flash, of the Jovian satellites at the moment of each impact. Backyard astronomers armed with large scopes and prime-focus photo rigs or CCD cameras may wish to capture the individual nuclei as they approach Jupiter, although they will be extremely faint.

Detecting the crashes means observing Jupiter's cloud features before the impacts occur. Any observable effects in the Jovian clouds will be noticeable only because the clouds change relative to their pre-crash appearances. So before each impact you'll need to observe and/or sketch Jupiter's cloud features all the way around the planet, chiefly in the zone between 40° and 50° south latitude. "Ground zero" will be at latitude 44° south, about 6° behind the planet's eastern limb as seen from Earth. Following the impacts, the effects may spread north and south as well as east and west from the point of entry. The region containing the zone of 44° south latitude is called the South South Temperate Belt, a thin, darkish belt that generally spans about 5° in latitude (but varies irregularly), and occasionally contains small white spots. Such white spots could easily be misconstrued as impact effects — again, get to know the region before the impacts occur.

The South South Temperate Belt appears about midway in latitude between the Great Red Spot and the planet's south pole. A trio of CCD images taken by Florida astrophotographer Don Parker in March 1994 shows the basic features in the planet's belts and zones as they should appear this July (above). The images are centered on central meridians of 72° (left, taken on March 10), 178° (center, taken on March 20), and 274° (right, taken on March 8), so together they show you an entire rotation of Jupiter's globe. Analyzing the appearance of the South South Temperate Belt in these images will help you anticipate telescopic views of the region during the strikes.

In the March 10 image, the South South Temperate Belt appears as a smooth, coppery-brown colored band with an edge that stands out sharply against the bright white border of the South Temperate Zone just north of it, near the center of the image. A prominent white spot lies between the Great Red Spot and the planet's south pole. Such a white spot may be relatively short lived and each of these features can shift position noticeably with regard to others north and south of it, because of the counterdirectional rotation of the planet's belts and zones. The March 20 image shows a South South Temperate Belt with irregular, arcing edges that loop around a bright white spot near the center of the image. Another white spot appears in the belt near the left edge of the image, and two huge white spots rest above it, lodged in the South Temperate Belt. The March 8 image shows a straight, thin South South Temperate Belt with a

A VIOLENT FORECAST FOR JUPITER'S CLOUDS

Fragment	**R.A.***	**Dec.**	**Separation†**	**Impact time**
A	**—**	**—**	**—**	**July 16, 3:55 p.m. EDT**
B	8.1s	2'28"	3'8"	July 16, 11:07 p.m. EDT
C	11.5s	3'4"	4'10"	July 17, 2:59 a.m. EDT
D	15.5s	3'47"	5'20"	July 17, 7:18 a.m. EDT
E	**17.9s**	**4'8"**	**6'2"**	**July 17, 11:30 a.m. EDT**
F	**24.3s**	**5'13"**	**7'55"**	**July 17, 8:40 p.m. EDT**
G	**28.5s**	**5'53"**	**9'6"**	**July 18, 3:52 a.m. EDT**
H	**34.8s**	**6'50"**	**10'56"**	**July 18, 3:47 p.m. EDT**
K	**43.0s**	**7'59"**	**13'11"**	**July 19, 6:39 a.m. EDT**
L	**48.4s**	**8'46"**	**14'43"**	**July 19, 6:40 p.m. EDT**
N	**54.0s**	**9'36"**	**16'19"**	**July 20, 6:21 a.m. EDT**
P	**56.2s**	**9'54"**	**16'55"**	**July 20, 11:27 a.m. EDT**
Q	**57.9s**	**10'12"**	**17'26"**	**July 20, 3:52 p.m. EDT**
R	**1m2.9s**	**10'52"**	**18'46"**	**July 21, 1:59 a.m. EDT**
S	**1m6.0s**	**11'17"**	**19'43"**	**July 21, 11:46 a.m. EDT**
T	1m7.3s	11'31"	20'4"	July 21, 2:16 p.m. EDT
U	1m8.5s	11'42"	20'26"	July 21, 8:25 p.m. EDT
V	1m11.4s	12'4"	21'12"	July 22, 12:06 a.m. EDT
W	**1m12.7s**	**12'14"**	**21'32"**	**July 22, 4:34 a.m. EDT**

*At the time of impact of fragment A, move west in R.A and south in Dec. these distances from the center of Jupiter to find each fragment.

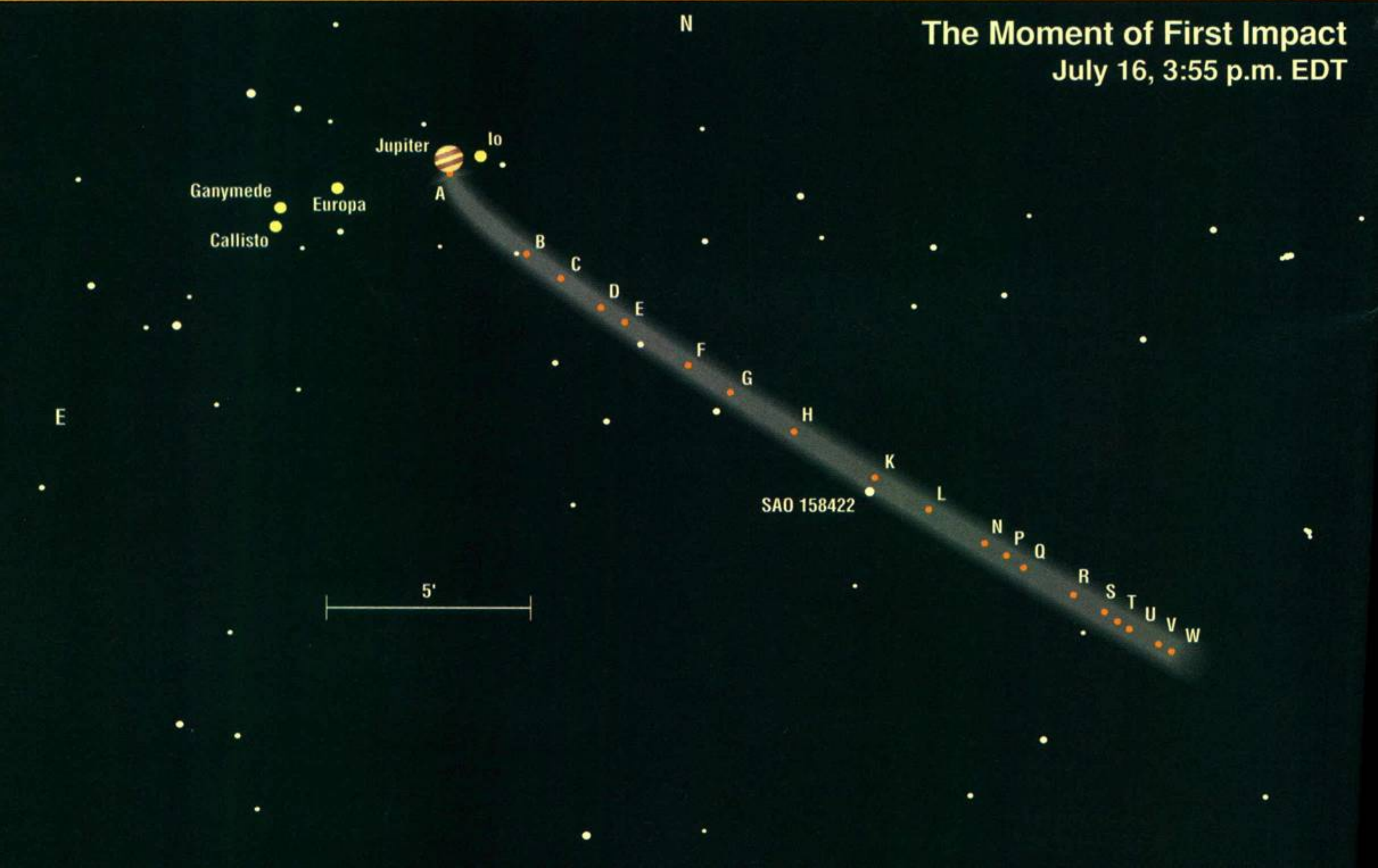
†Separation from center of Jupiter at impact of fragment A.

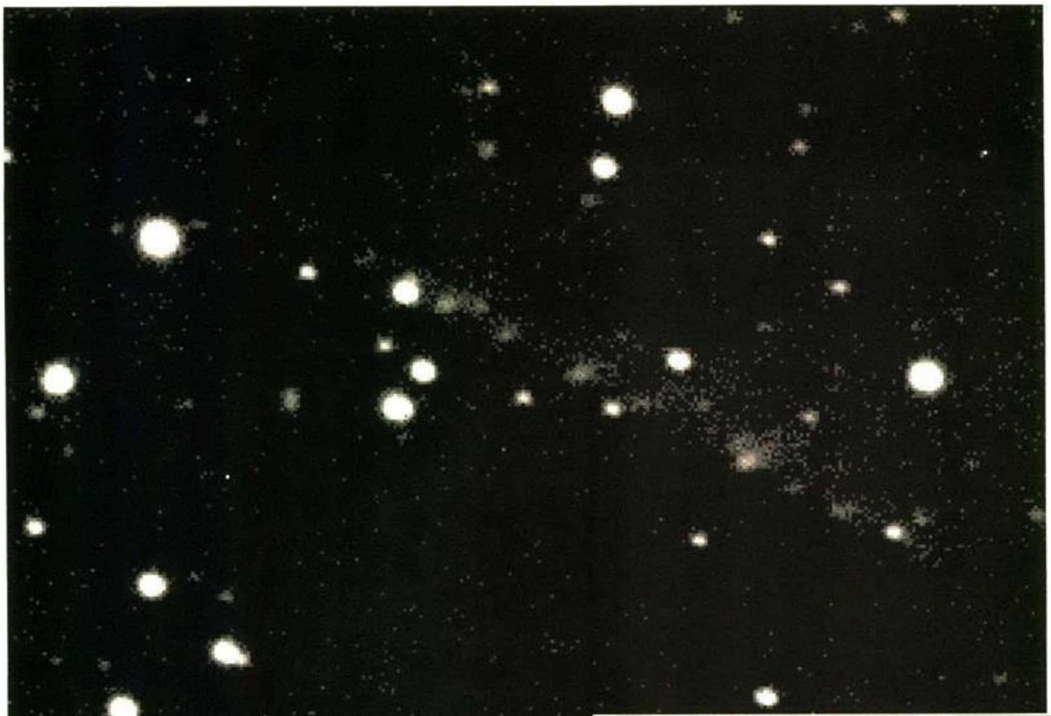
The fragments in **bold** above are those with known independent orbits; the others have less precise orbits.

All data provided by Paul Chodas, Jet Propulsion Laboratory.

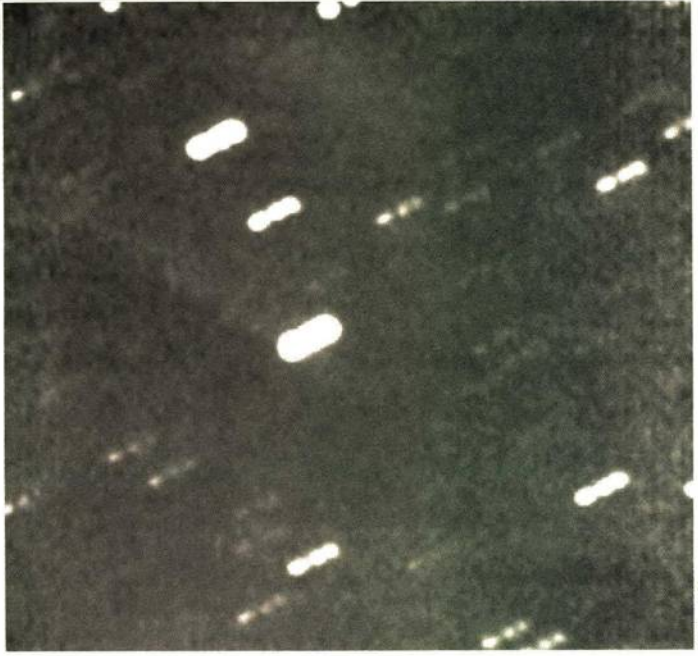
The Moment of First Impact

July 16, 3:55 p.m. EDT





Ronald W. Kohl



Richard Berry

THE LATEST PHOTOS OF COMET SHOEMAKER-LEVY 9 show its spreading fragments on April 8, 1994 (above, taken by Ronald W. Kohl) and May 3, 1994 (right, taken by Richard Berry). Both are CCD images; Berry's was made with a 6-inch f/5 reflector.

small white spot near the right limb. A prominent white spot lies near the left edge in the South Temperate Belt.

Having studied these images and observed the planet for the first couple of weeks in July, you'll be as ready as you can be to detect abnormal Jovian cloud activities. The other observing opportunities — spotting a flash from a Jovian satellite and imaging a comet fragment as it moves in toward Jupiter — are bound to be much more difficult. The greatest chance for seeing satellite flashes comes with Io and Europa, the two Galilean satellites that will be closest to Jupiter. The variation in light reflected from these satellites will be slight, however, amounting to a small fraction of a magnitude for an instant. In order for us to see a flash, the satellite has to be in shadow, in the line-of-sight to the impact zone, and in view from Earth. From North America, the best opportunities are flashes of Io and Europa caused by fragments B and F, at 11:07 p.m. EDT on the 16th and 8:40 p.m. EDT on the 17th, respectively. Visible in other parts of the world will be a possible flash from Europa in eclipse caused by fragment K.

If you can't wait for a flash at the moment of impact, you may wish to try imaging some of the comet's fragments as they draw close to the giant planet. This will require a large telescope operating at prime focus, a dark sky, and high-resolution film such as Tech Pan or a CCD camera. The strict requirement for success results from the extremely faint magnitudes of individual Shoemaker-Levy 9 fragments. In April astronomers at the U.S. Naval Observatory in Flagstaff measured the brightnesses of the six brightest fragments and determined the following magnitudes: 19.1 (Q), 19.5 (G), 20.1 (K), 21.1 (H), 21.1 (S), and 21.5 (L). That makes the fragments faint but within the limits of the largest backyard scopes armed with photographic or electronic imaging equipment. Can any reader produce a portrait of the comet's brightest fragments this month?

Though recording the individual pieces and seeing the flashes from the Jovian moons may be elusive goals, it's likely you'll detect some cloud changes on Jupiter in the hours and days following the impacts. The evidence will be subtle. If you detect it, you will be lucky enough to have witnessed a momentous event in the recent history of the solar system. ☐

Astronomy: Steve Davis

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6.6"-8.5"	117.00	87.00	152.00
8.6"-10.5"	127.00	97.00	166.00
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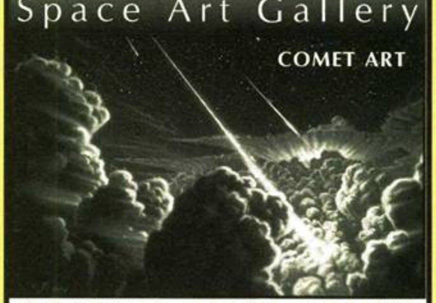

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Supernova in the Whirlpool

April Fool's Day packed a big surprise for five amateur astronomers this year. On that evening in Cedar Grove, Wisconsin, Richard Berry was taking a series of CCD images of the Whirlpool Galaxy (M51) in Canes Venatici. Similarly, Southern Californians Wayne Johnson and Douglas Millar were setting their telescope for electronic imaging. Outside of Atlanta, Tim Puckett and Jerry Armstrong were observing galaxies. That evening these observers from three states would discover a supernova, later designated 1994I, just 12" from the nucleus of this bright and familiar galaxy. (Berry's prediscovery image was published in AstroNews in the July issue, and Johnson and Millar's image taken that night appeared in the July Reader Reports.)

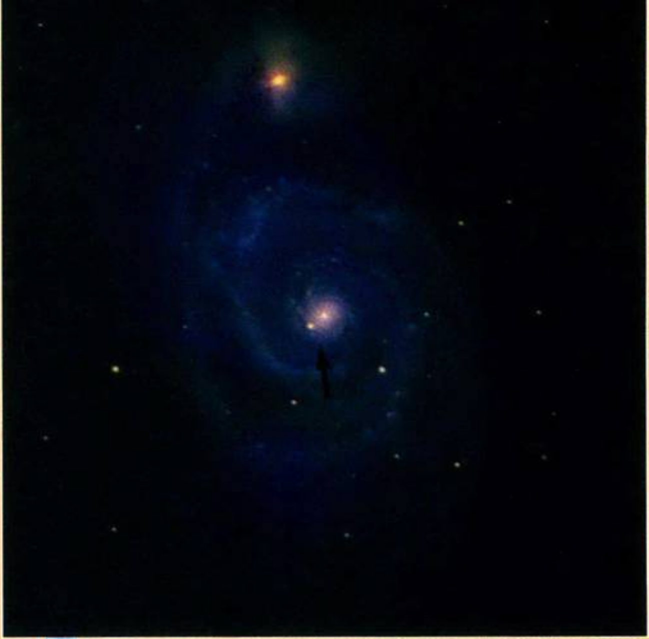
The supernova proved one of the brightest recent new stars, rising from 12th magnitude at discovery to magnitude 10.5 before slowly fading to fainter than 13th magnitude by late April. The images of the supernova included here represent a small sampling of the early submissions to ASTRONOMY. We will publish many more images in the coming months and encourage you to submit photos and CCD images showing the supernova.

Early Warning on Novae and Supernovae. The American Association of Variable Star Observers (AAVSO) issues *Alert Notices* whenever a bright nova or supernova appears or when variable stars warrant special attention. These missives keep AAVSO members abreast of the rapid discoveries and changes associated with these stars. "Thanks to *Alert Notices*, I was able to monitor Nova Cassiopeiae 1993 last December when it was a 6th-magnitude object," says Phil Dombrowski of Glastonbury, Connecticut. "Not to be outdone," he says, "the next *Alert Notice* heralded the arrival of Supernova 1994D in NGC 4526, allowing me to watch the star from the spring equinox to mid-April." Another recent notice quickly warned members about Supernova 1994I in the Whirlpool Galaxy. For more information on *Alert Notices* and membership in the AAVSO, contact Janet A. Mattei, director, AAVSO, 25 Birch Street, Cambridge, MA 02138.

Messier Marathoning in Illinois. On the night of March 15/16 Jeff Copland and Ed Neuzil of Prospect Heights, Illinois, set out to undertake a Messier Marathon (see "Running a Celestial Marathon," March 1994). Setting up on a friend's farm in Belvidere under a sky showing naked-eye stars down to 5th magnitude, the two unlimbered an 8-inch reflector and a 14-inch SCT. "Even with the 3-day-old Moon lurking nearby, the early evening objects were easy to spot," says Copland. "These included the Andromeda Galaxy, M32, M33, M77, M79, and M110."

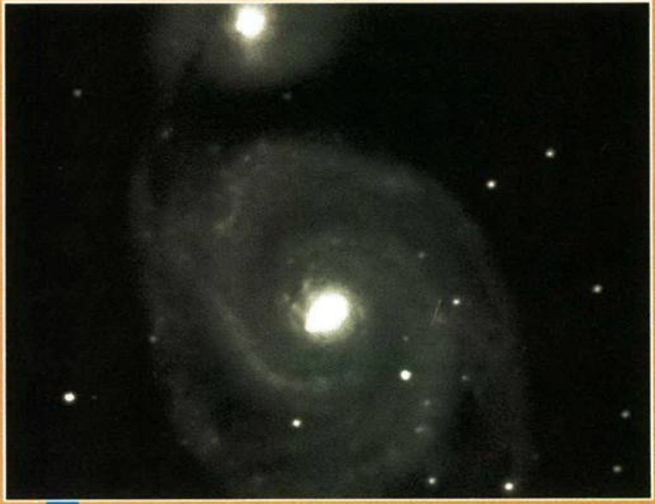
Using the March ASTRONOMY article, the Illinois observers picked off M object after M object, working their way toward the thickly populated Realm of the Galaxies in Virgo and Coma Berenices." Observing the galaxies turned out not to be a problem," says Copland. "We viewed the galaxies in that area in a scant 15 minutes. But as dawn approached we knew we had to hustle."

The two spotted the globular clusters along the base of the Teapot in Sagittarius before twilight began erasing the morning stars. "I frantically looked for M15 in Pegasus before finally spotting it," Copland says. The sky was now brightening fast and the two decided to pack it in. The count? They had viewed 106 M objects. "We had a fantastic time," says Copland. "I recommend it highly — it's great!"



Supernova 1994I (arrow) in M51

by Michael Stecker
(14-inch SCT at f/11, hypersensitized Fuji Super HG 400 film, 90-minute exposure on April 16, 1994)



Supernova 1994I in M51

by Ronald W. Kohl
(20-inch Cassegrain, STAR I CCD camera, taken on April 8, 1994)

ASTRONOMY wants to hear about your observations of the sky. Send reports, sketches, and photographs to David J. Eicher, Reader Reports Editor, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187. Please label each photo with your name, address, and social security number. You may send written reports via Internet to: 72000.2704 @CompuServe.com

Comet McNaught-Russell and Open Cluster NGC 1647

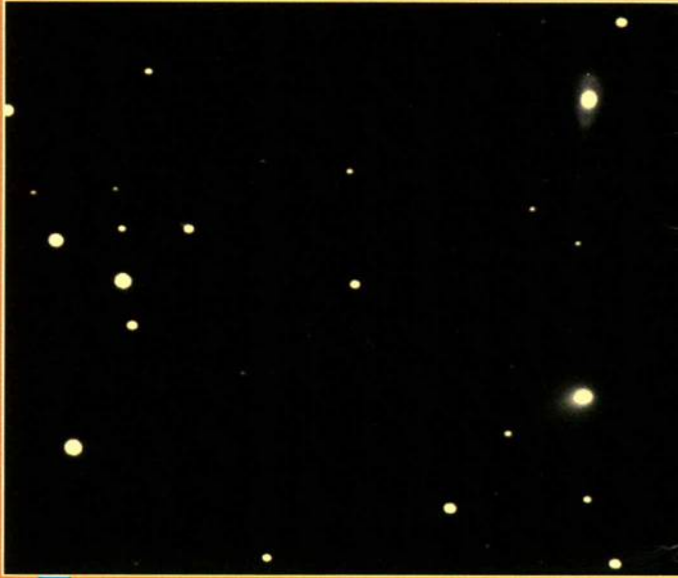
by Alan Dyer
(4-inch f/4.5 refractor, ScotchChrome 400 film, 10-minute exposure on April 1, 1994)

Comet McNaught-Russell

by Mansfield Clinnick
(8-inch f/4 reflector, Ektar 1000 film, 20-minute exposure on April 4, 1994)

IN ORBIT OVER COPERNICUS

Belgian astrophotographer Leo Aerts specializes in shooting high-resolution portraits of the Moon filled with astonishingly crisp detail. Aerts' recent photo of Copernicus, shot with a 12-inch reflector and Tech Pan film, wins this month's $100 "Best Astrophoto" award.



Comet Schwassmann-Wachmann 2 and Galaxy NGC 2545

by Ronald W. Kohl
(20-inch Cassegrain, STAR I CCD camera, 6-minute exposure on March 1, 1994)

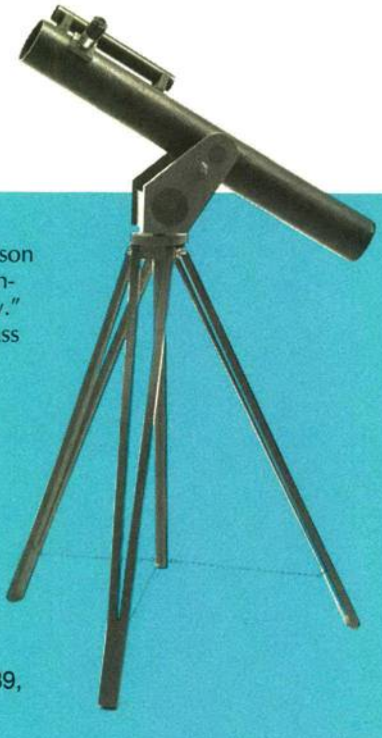
Comet Tempel 1

by Ronald W. Kohl
(20-inch Cassegrain, STAR I CCD camera, 5-minute exposure on March 12, 1994)

Copernicus

by Leo Aerts
(12-inch f/8 reflector, Tech Pan film, 2-second exposure on February 20, 1994)

NEW PRODUCTS



Beginner's Reflector

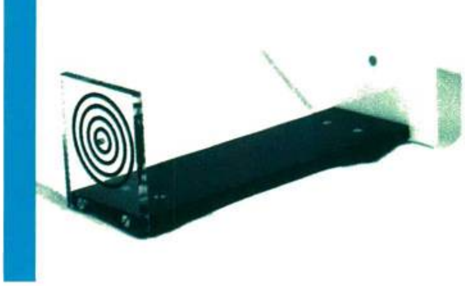
Canadian telescope maker Steve Dodson has reintroduced what he calls the "beginner's reflecting telescope of days gone by." His telescope uses a 3-inch f/10 plate glass mirror in a 31-inch tube mounted on a wooden altazimuth fork and tripod. Included is a push-pull focuser and a standard size ($1\frac{1}{4}$") 18mm Kellner eyepiece that yields 42x and a $1\frac{1}{4}$ degree field of view. Attached to the telescope tube is a sighting tube for use as a naked-eye finder. Total weight of scope and mount: 7 pounds. Call or write for free demonstration video.

Steve Dodson, 1752 Rutherglen Crescent, Sudbury, Ontario, P3A 2K3, Canada, (705) 566-1314. $189, plus $29 shipping (U.S. funds).

Scale Model of Voyager Spacecraft

Space Craft International now offers an improved version of its 1:32 scale model of Voyager you can build yourself. Components are pressed out of stiff cardboard, lithographed, and embossed, in some areas with metal foil. This latest release has better science boom detail and a high-gain antenna made out of molded styrofoam. The kit includes an up-to-date spacecraft and mission profile fact sheet. Write for a free catalog of other kits.

Space Craft International, P.O. Box 61027, Catalina Station, Pasadena, CA 91116-7027, (800) 472-4548 or (818) 794-0177. $14.



SSP-14 Solar Spotter

Trying to safely center the Sun in your telescope's eyepiece has been an exercise in shortest-shadow guesswork. Not now. When the Sun's image is projected on the SSP-14 Sun finder's bull's eye, it should be centered in your eyepiece. The finder, designed to fit into a Telrad base, is made of thick acrylic.

Astronomical Innovations, P.O. Box 14853, Lenexa, KS 66285, (913) 894-5775. $22.95; Telrad bases: $8.

Carl Zeiss-Jena Binoculars

Sunset Cliffs Manufacturing is offering the last commercial-grade binoculars fabricated by the original Carl Zeiss-Jena factory in eastern Germany. Built prior to the reunification of Germany, these glasses are all new and will be the last to carry the original (since 1846) Carl Zeiss-Jena name. Ten different models are available from 8x32 through 15x60. All binoculars come with a lifetime warranty. Call for a complete catalog.

Sunset Cliffs Merchandising Corporation, P.O. Box 7518, San Diego, CA 92167, (800) 225-9407. Prices start at $199.

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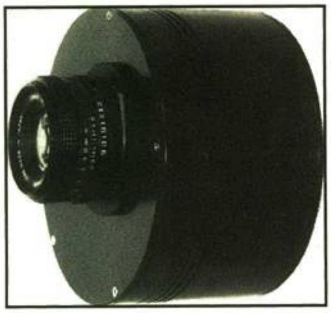

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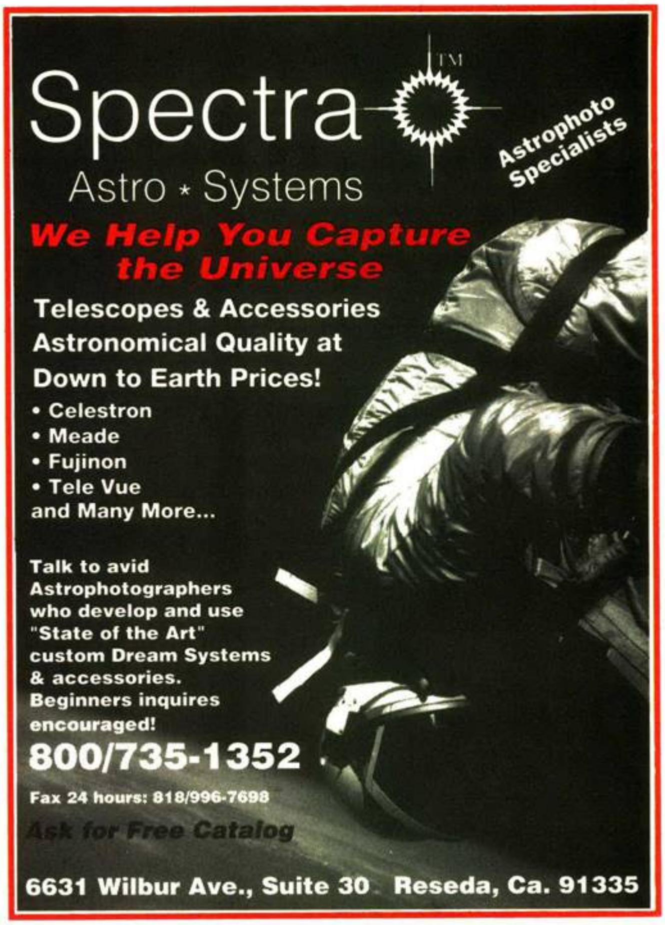

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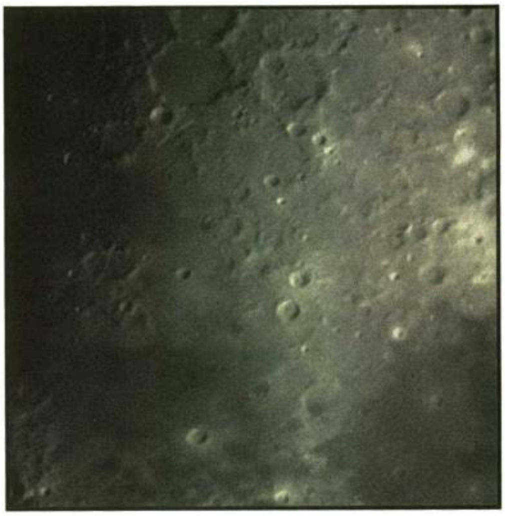

Lunar Terminator. *Single 0.4 second CCD image taken at the prime focus of a C-11 apertured down to 2.5 inches. Courtesy SBIG.*

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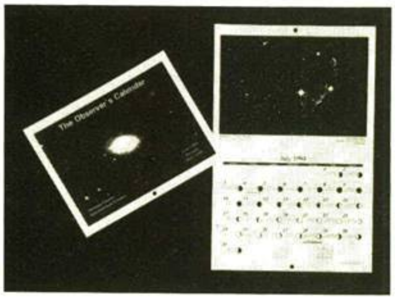
Jim's Mobile Inc., 810 Quail Street, Unit E, Lakewood, CO 80215, (303) 233-5355. NGC-microMAX: $449; NGC-miniMAX: $569; NGC-MAX: $769. Add $5 for shipping.



Observer's Calendar

Southern California amateurs might find the Ventura County Astronomical Society's *Observer's Calendar* a handy item. Running from June 1994 through May 1995, the calendar provides Southern California moonrise and moonset times as well as lunar phase information. Each month features an amateur B&W astrophoto and its technical information. Printed on glossy card stock.

Ventura County Astronomical Society, P.O. Box 892, Simi Valley, CA 93062, (805) 527-3952. $7.50.

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Augen Optics, 947 Parkside Lane, Lancaster, PA 17601, (717) 295-4679. 6": $675; 8": $1,050; 10": $1,600.

Amateur Astronomy Magazine

This past spring Florida amateur Tom Clark introduced a new quarterly publication devoted to, in his words, "the fun of being an amateur astronomer." Coverage will include stories on club projects, star party reports, observing reports, telescopes, and telescope making.

Amateur Astronomy, 2111 Whitfield Avenue, Sarasota, FL 34243, (813) 758-9890, fax (813) 753-6766. One year subscription: $18 U.S., $24 Canada, $32 elsewhere; sample issue: $4.95.

Amateur Astronomy
1
Observing Under the Darkest Skies in the World
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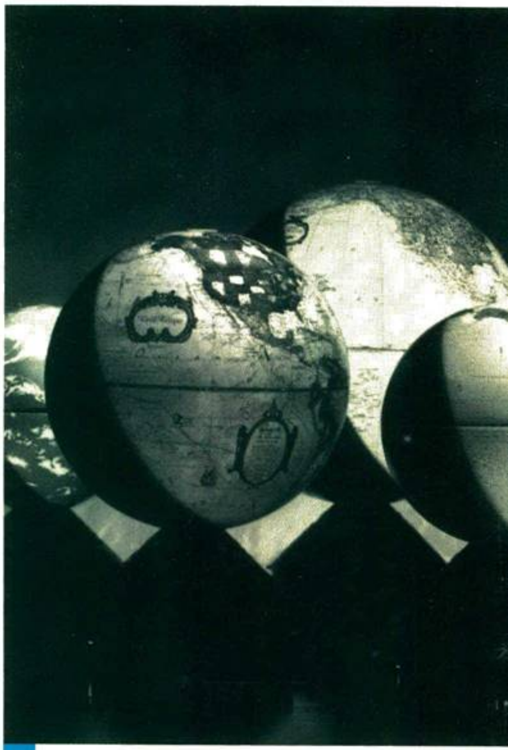

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Loranda, Inc., 327 Cardinal Way, Stuart, FL 34996-2601, (407) 288-3829. 12-inch: $295; 16-inch: $495; 20-inch: $1,195 (Living Earth only). Starship Earth design available in 12-inch only: $335. Add $12 per globe for shipping.

This department presents new product announcements issued by their manufacturers. Product information is as supplied by the manufacturers or distributors. All prices are suggested retail. Suppliers should send their product announcements to the attention of John Shibley.

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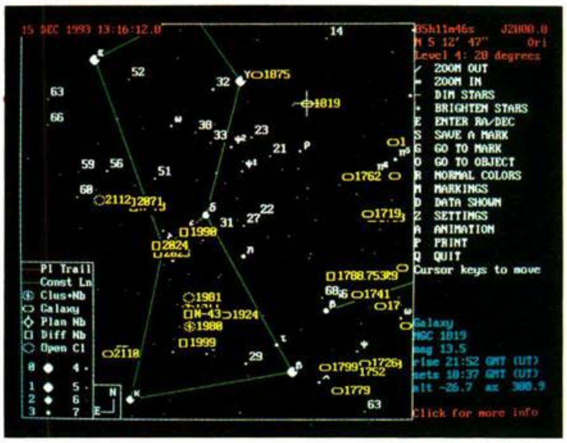
Guide attempts to bridge the gap between planetarium-type programs and deep-sky charting programs. Like planetarium-type programs, it provides constellation lines and coordinate grids and displays wide-angle views of the sky but no horizon views. Here, *Guide* acts more like a deep-sky program and displays the altitude and azimuth of an object so you can mentally determine where it appears in the night sky. The field of view can range from 180° down to 1".



```
Galaxy
NGC 1819
mag 13.5
rise 21:52 GMT (UT)
sets 10:37 GMT (UT)
alt -26.7 az 300.9
```

ASTRONOMY: Darla Evans

The stellar database contains more than 15 million stars down to 15th magnitude from the Hubble *Guide Star Catalog*. You can find a star by entering its common name, Bayer (Greek letter) designation, Flamsteed number, Yale *Bright Star Catalogue* number, Smithsonian Astrophysical Observatory catalog number, or *Guide Star Catalog* number. Clicking on a star displays its Bayer and Flamsteed designations, right ascension, declination, magnitude, rise and set times, altitude and azimuth, and additional information such as spectral type and data on companion stars. This list unfortunately changes according to field size, with the program "forgetting" information as you zoom in on the field.

Other databases contain the planets, the four Galilean satellites of Jupiter, 50 comets (you can add to this list), 5,200 asteroids, 28,000 stars from the *General Catalog of Variable Stars*, 14,000 stars from the *New Catalog of Suspected Variable Stars*, all of the deep-sky objects in the *New General Catalogue*, and 30,000 galaxies from other sources. You can turn these catalogs on and off depending upon what charts you are trying to produce. An animation feature lets you watch Jupiter's satellites orbit the planet or the planets move across the sky.

The program includes precession, which is the change in an object's position caused by the wobble in Earth's rotational axis, so you can find an object's position over a wide range of dates. The planetary calculations are most accurate between about 2000 B.C. and A.D. 6000 (those for Pluto are best between A.D. 1885 and 2099 and for asteroids between A.D. 1968 to 2017).

The display always lists the right ascension, declination, and constellation region of either the center of the field or the last object clicked on. The display also indicates the size of field. For functions such as "go to object," you can use a menu, type in a name, or use an on-screen "keyboard" that lets you "type" a name using the mouse. This last method is useful at the telescope when the real keyboard is hard to see. *Guide* also has a red-screen mode that is great for preserving your night vision if you use the program at the telescope.

Guide has a number of other useful features. It can accept Julian dates for the time, show a circular aperture to represent an eyepiece or finderscope field of view, and invert and mirror charts to match the view in an eyepiece. You can print sky charts on a number of printers, including dot-matrix, HP LaserJet, and PostScript laser printers or produce PCX format files for use with other programs. Auto modes will automatically turn constellation lines, labels, and certain objects on and off depending upon field size. A glossary provides definitions of astronomical terms and on-screen help gives information about various program features.

One complaint is that information in the manual is sometimes hard to find. For example, information on forcing a screen redraw is contained in an appendix. Sample screen shots would help demonstrate commands. But *Guide* is simple to use and you rarely need to use the manual, so this is a minor problem.

Reader's Exchange

ANNOUNCEMENT. The Greek Amateur Astronomers Society was formed in April, 1993 and is looking for new members from all over Greece. For information and registration forms, please contact Nicholas Matsopoulos, President, Pentelis 46, 151 26, Maroussi, Athens, Greece.

FOR SALE. Astronomy, space, Star Trek, sci-fi, and rock n' roll art. Contact Ron Beck, Rt. 1, Box 101, Alexander, IL 62601, (217) 478-2461.

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2.4"	$49.00	2.4"	$39.00
3.1"	52.00	3.1"	42.00
3.5" to 4"	59.00	3.5 to 4"	49.00
4-1/4" to 5"	74.00	4-1/4" to 5"	64.00
6"	79.00	6"	69.00
8"	95.00	8"	85.00
10"	109.00	10"	99.00
11"	119.00	11"	109.00
12.5" to 13.1"	149.00	12.5" to 13.1"	129.00
14"	169.00	14"	149.00

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Aperture	Mounted	Aperture	Unmounted
2.4"	$62.00	2.4"	$52.00
3.1"	65.00	3.1"	55.00
3.5" to 4"	76.00	3.5 to 4"	66.00
4-1/4" to 5"	96.00	4-1/4" to 5"	86.00
6"	105.00	6"	95.00
8"	125.00	8"	109.00
10"	139.00	10"	129.00
11"	149.00	11"	139.00
12.5" to 13.1"	179.00	12.5" to 13.1"	159.00
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Steve Voss, 595 Carina Drive, Lompoc, CA 93436. Minimum requirements: IBM PC-compatible computer, DOS 2.1, 192 KB of free memory, and 128 KB of hard disk space. Supports IBM Proprinter, Epson FX, and Epson LQ dot-matrix printers. Price: $24.50; $25.50 for 3.5" disk.

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Comet Crash Watch, Farpoint Observatory, Eskridge, Kansas. Sponsored by the Northeast Kansas Amateur Astronomers' League, Inc. Contact Brenda Culbertson, NEKAAL, P.O. Box 951, Topeka, KS 66601, (913) 589-2405.

July 28-30
ALCON '94, Avila College, Kansas City, Missouri. Sponsored by the Astronomical Society of Kansas City. Contact Carroll Iborg, 7241 Jarboe, Kansas City, MO 64114.

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Annual Meeting, Theodore Roosevelt National Park, Watford City, North Dakota. Sponsored by the Dakota Astronomical Society. Contact Eric Raveling, 9115 Baine Drive, Bismark, ND 58501, (701) 224-8420.

August 5-7
Annual Summer Star Party, Foxpark, Wyoming. Sponsored by the Cheyenne Astronomy Society. Contact Marty Curran, 6614 N. College, #G, Cheyenne, WY 82009, (307) 635-5944.

August 5-7
Eastern Iowa Star Party, Wapsi River Environmental Center, near Dixon, Iowa. Sponsored by the Quad Cities Astronomical Society, Inc. Contact Lori Brown, P.O. Box 3706, Davenport, IA 52808, (309) 786-9622.

August 5-7
Starfest '94, River Place Campground, Mount Forest, Ontario. Sponsored by the North York Astronomical Association. Contact Andreas Gada, 26 Chryessa Avenue, Toronto, Ontario, Canada M6N 4T5.

August 6-10
Asimov Seminar, Rensselaerville Institute, Albany County, New York. Contact The Asimov Seminar, P.O. Box 54, Rensselaerville, NY 12147, or call Don McGrain (609) 629-3732.

August 10-14
1994 Mount Kobau Star Party, near Osoyoos, British Columbia. Contact Peter Kuzel, 4100 25th Avenue, Vernon, B.C., Canada V1T 1P4, (604) 545-1226.

August 12-13
Summer Spectacular, Lemon Lake Park, Crown Point, Indiana. Sponsored by the Calumet Astronomical Society. Contact Stephen J. Miller, Calumet Astronomical Society, (219) 845-9174.

August 12-14
10th Annual Southern Idaho Regional Star Party, Bruneau Dunes State Park, south of Mountain Home, Idaho. Sponsored by the Boise Astronomical Society. Contact Richard Beaver, (208) 377-5220.

August 12-14
Summer Seminar, Darling Hill Observatory, Tully, New York. Sponsored by the Syracuse Astronomical Society and the Darling Hill Observatory. Contact Robert Ostrander, 1115 E. Colvin Street, Syracuse, NY 13210, (315) 479-7282.

August 13
Summer Star Party, Portsmouth Campus, Tidewater Community College, Virginia. Sponsored by the Tidewater Community College. Contact R. H. Stewart, 1064 Dune Street, Norfolk, VA 23503, (804) 583-9397.

August 30-September 4
Queensland Astrofest 1994, near Brisbane, Australia. Sponsored by the five astronomical societies in the Brisbane area. Contact Peter Adam, Queensland Astrofest, 50 Davrod Street, Roberton, Queensland 4109, Australia, call or fax to (07) 345-6025.

September 2-5
Fourth Annual Huronia Star Party, Lisle, Ontario. Sponsored by the South Simcoe Amateur Astronomers. Contact Henri Van Bemmel, #1502-140 Erskine Avenue, Toronto, Ontario, Canada M4P 1Z2, (416) 481-9937.

September 2-5
The Conjunction — Arunah Hill Weekend, Northfield Mountain Environmental Center, Northfield, Massachusetts. Contact Jack Megas, 311 Surrey Road, Springfield, MA 01118.

September 9-11
AstroFest, Camp Shaw-Waw-Nas-See, Kankakee, Illinois. Sponsored by the Chicago Astronomical Society. Contact Alan Birkner, Chicago Astronomical Society, P.O. Box 596, Tinley Park, IL 60477, (708) 966-6214. □

Please submit announcements at least four months in advance to Tracy Staedter, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187-1612. When writing to organizations listed in "Meetings and Events," include a large, self-addressed stamped envelope with your request for information.

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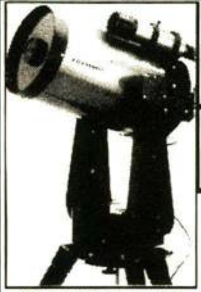

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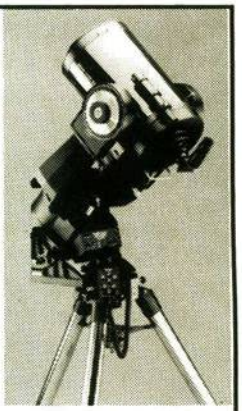

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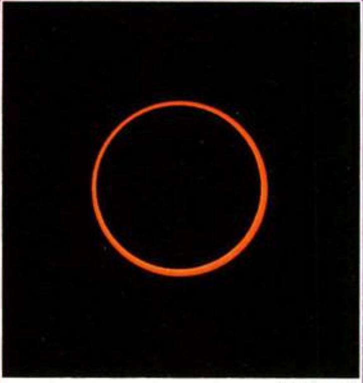

Chris Cook

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Readers travel far and wide to see and photograph the grand ring of fire.

CANDLES THAT LIGHT THE NIGHT
Astronomers focusing on the faint light of distant objects have greatly improved their yardsticks for measuring the universe.

HOT OFF THE PRESSES Clementine, the United States' latest space probe, has finished mapping the Moon. Here's the best of what it saw.

BEAT BACK THE GUIDING GREMLINS What's the secret to super-sharp astrophotos? Astrophotographer Alan Dyer shares his tricks for taking great images.

AVAILABLE ON
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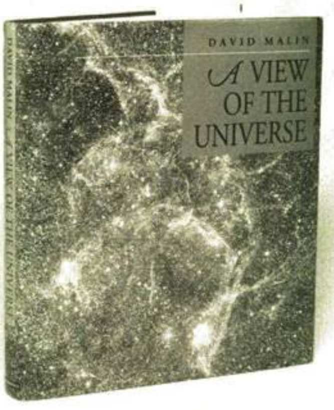
AUGUST 9

ASTRONOMY BOOKS

Universe in Living Color

A View of the Universe
David Malin, (Cambridge University Press, 1993), ISBN 0-521-44477-2, 265 pages, hardcover, $39.95.



ASTRONOMY: Jim Forbes

One could call David Malin the Ansel Adams of modern astrophotography. As Adams did with nature photography, Malin combines the hard science behind photography with the artist's eye to produce many of the most stunning photographs of the universe. *A View to the Universe* is packed with the best of these images, from simple tripod-based star trail pictures to long-exposure, unsharp-masked images taken with a 4-meter telescope. In this book Malin presents both a summary of the universe and his efforts to image it.

David Malin begins with a brief personal introduction and an overview of his photographic techniques. He was a chemist living in England when he made his jump into astronomical imaging by responding to an ad placed in *Nature* for a person willing to establish photographic laboratories for the Anglo-Australian Telescope in Australia. Upon arrival in Sydney, he discovered that AAT's darkroom was a 21 square-foot concrete block room with no equipment, running water, or electricity. Working from scratch, Malin went on to formulate and apply film hypersensitizing and unsharp-masking techniques to produce views of the universe such as the world had never seen. His pioneering work to enhance photographic information has led to a better understanding of our universe, such as when he detected light "echoes" reflecting off material surrounding 1987's supernova in the Large Magellanic Cloud.

But landing fantastic photos and interpreting what they reveal about the universe are two different issues. *A View to the Universe* gives the reader an overview of our current knowledge of the universe. Chapters delve into the nature of stars, interstellar dust, nebulae of all sorts, star clusters, galaxies, and clusters of galaxies. For example, Malin conducts a tour of star-forming regions in our galaxy, intertwining photos of objects like M16 in Scutum and S Monocerotis with insights into what's happening deep within their dusty confines.

In the chapter on galaxies, he demonstrates how powerful a tool photography can be in the discovery of new objects. Side by side are two photos dominated by NGC 4571, a Virgo Cluster spiral. One image shows the field as seen on a UK Schmidt telescope plate. The other image shows the same area but combines four separate, photographically enhanced plates. It shows a faint smudge directly above NGC 4571, the faint diffuse galaxy named after the person who discovered it: Malin 1. Such is the potential of photographic imaging.

The approach Malin takes to this subject in the text is clear and a good read for non-professionals. Of great help is the fact that pertinent text is placed near the photograph it seeks to explain, an excellent feature for browsing. Often I found myself lighting on an interesting picture and then glancing at the narrative to learn more about that particular object.

A View of the Universe is a book for all sorts of audiences. For browsers, it rates high as a coffee table book. For the interested layman, it's a good way to learn what we presently know about the universe. Given the detailed photography, I wouldn't even be surprised if amateur astronomers with large telescopes trudged out under dark skies with a copy of *A View of the Universe* to see if they could glean visually the subtleties Malin has collected photographically. — *Robert Bunge*

Recent Releases

Space Satellite Handbook, Third Edition
Anthony R. Curtis, (Gulf Publishing Company, 1994), ISBN 0-88415-192-1, 358 pages, hardcover, $39.

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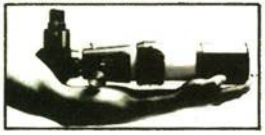

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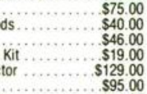

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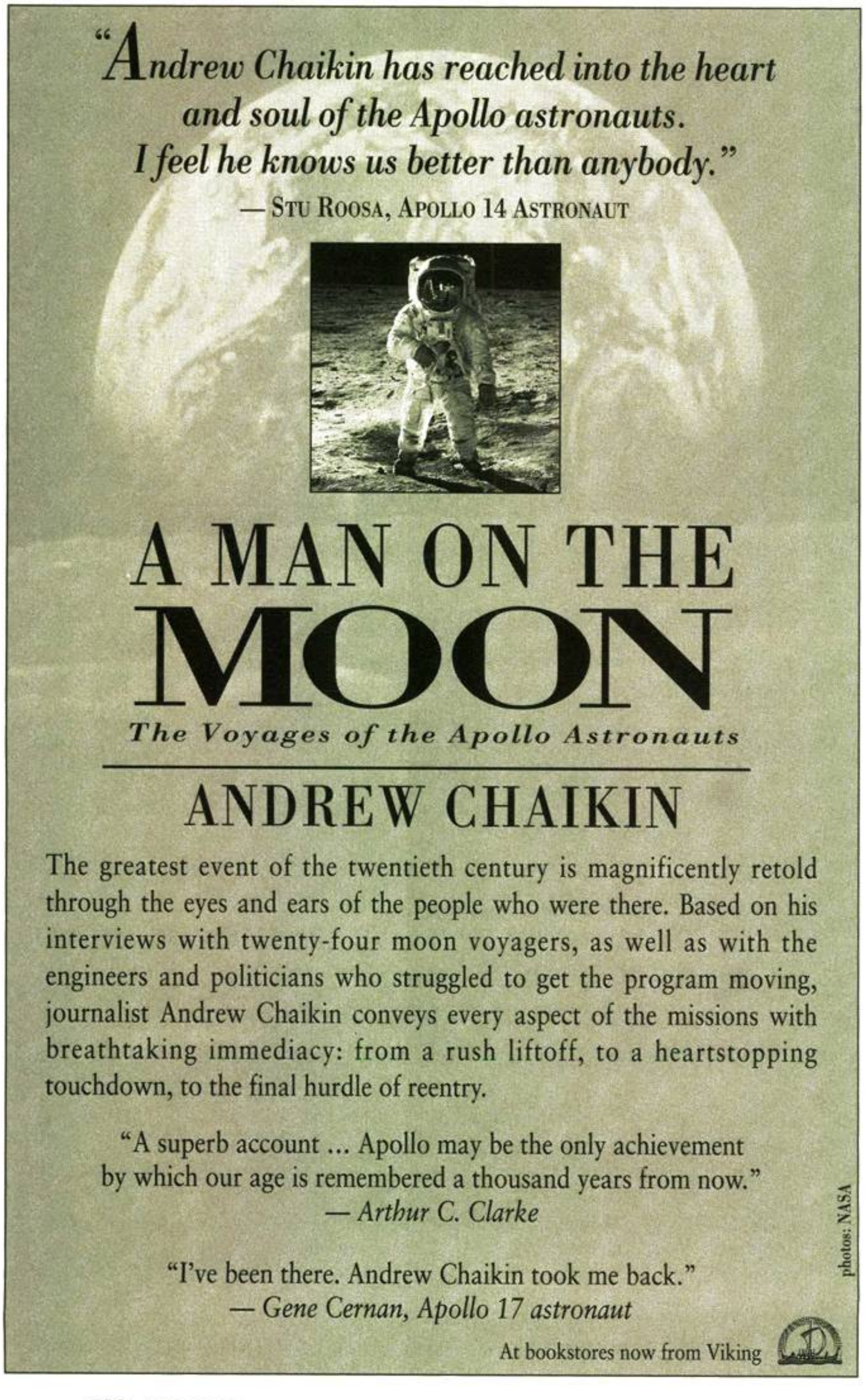

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book. The first nine chapters give satellite program histories — communication, military, and manned. Each project has a brief description plus a host of little-known facts and statistics, a space buff's trivial pursuit dream come true. Following a glossary section of pertinent terminology is a master list of satellites in orbit broken down by launch year. Included in this section is orbital data such as the satellite's perigee, apogee, inclination, and period. Curtis provides a reentry date if the craft is no longer in orbit. For both casual reading and reference, this book is perfect for the satellite tracker's bookshelf.

Dictionary of Minor Planet Names

Lutz D. Schmadel, (Springer-Verlag, 1993), ISBN 3-540-57260-0, 741 pages, hardcover, $69.

Naming an asteroid is a privilege reserved for whoever discovers it, a tradition since 1 Ceres was found in 1801. This dictionary (updated in this second edition) provides the names and their meanings for all asteroids discovered and numbered through May 1993 (5,000-plus and counting). Organized by asteroid number, each entry has information on the discoverer of the asteroid, its discovery date, and the observer's location. Appendices give the number of asteroids by family and namesake (mythological terms, Nobel laureates, countries, geographical features, etc.). A comprehensive index allows access to an asteroid entry by name only. If you've ever wondered what the story is behind 975 Perseverantia's name, this book's for you!

Chasing the Shadow

Joel Harris and Richard Talcott, (Kalmbach Books, 1994), ISBN 0-913135-21-6, 160 pages, softcover, $18.95.

After opening with some historical and scientific background on solar eclipses, this guide will tell you how to mount a solar eclipse expedition, down to providing equipment, travel, and logistical tips. Chapters also deal with capturing the eclipse on film and viewing it safely. The last half of the book details solar eclipses well into the next century. For every total and annular eclipse through 2020 there is a description of the path and local circumstance data for where greatest eclipse occurs (latitude, longitude, solar altitude and azimuth, and eclipse magnitude). For this century's five remaining total eclipses, there are sky maps depicting the visibility of planets and 3rd-magnitude stars during mid-eclipse. ☐

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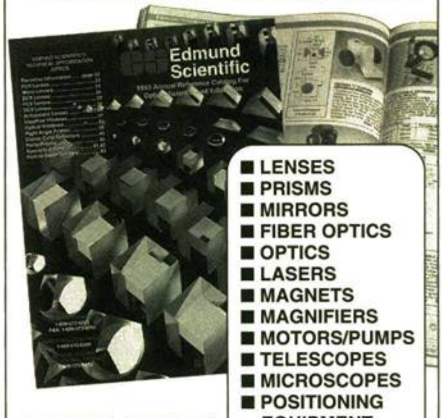

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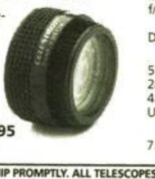

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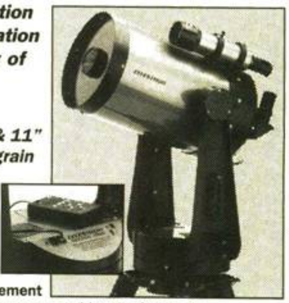

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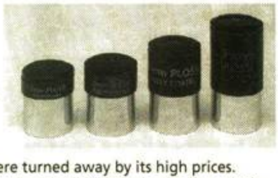

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READINGS & CREDITS

Chiron (page 26)

"The Origin of the Solar System" by Gerard Kuiper in *Astrophysics: a Topical Symposium*, edited by J. Allen Hynek, (McGraw-Hill, 1951). The paper that gave birth to what's now called the Kuiper disk or belt. (Try a large library.)

Moons and Planets by William K. Hartmann, (Wadsworth, 1993). This is the best introduction to the solar system and its contents available. It is easily readable by any interested layperson.

Asteroids II by Richard P. Binzel, Tom Gehrels, and Mildred Shapley Matthews (University of Arizona Press, 1989). The most thorough compilation of information on asteroids, including Chiron, to date. (It does not include the "QB$_1$s," however, which were discovered after the book was published.)

Big Ears (page 34)

"The Birth of Radio Astronomy" by Robert Wearner, ASTRONOMY, June 1992. Describes early research efforts by radio astronomy pioneers Karl Jansky and Grote Reber.

"The Very-Long-Baseline Array" by Kenneth Kellermann and Richard Thompson, *Scientific American*, January 1988. Two of the designers of the array describe how the array works and what they hope to observe with it.

Dark Matter (page 40)

The Shadows of Creation by Michael Riordan and David Schramm, (W. H. Freeman and Co., 1991). Describes how dark matter affects the structure of the universe.

The Dark Matter by Wallace Tucker and Karen Tucker, (William Morrow and Co., 1988). Explains gravitational lensing and decribes searches for different forms of dark matter.

Digital Darkroom (page 62)

Astronomical Image Processing by Richard Berry, (Willmann-Bell, 1991). A further exploration into the nuts and bolts of image-processing. Comes with IBM PC-compatible image-processing program.

Stormy Perseids? (page 68)

Meteor Showers: A Descriptive Catalog by Gary W. Kronk (Enslow, 1988). Includes extensive data on the Perseid meteor shower and tips on how to view it. Also provides information on several dozen other showers that are visible each year.

The End of the Line (page 72)

"Countdown to the Big Comet Crash" by David Bruning (ASTRONOMY, June 1994). Describes what astronomers hope to see of the collision of Shoemaker-Levy 9 and Jupiter and what the results may reveal about planetary atmospheres. Also includes a table of impact times for the major 21 fragments.

Cover: Don Davis; **p. 4, top:** William K. Hartmann; **bottom:** NRAO/AUI; **p. 5, top:** Charles Alcock, et al./Lawrence Livermore National Laboratory; **bottom:** Jack Newton; **p. 18:** NRL/Department of Defense; **p. 20, top:** Schuler Van Dyk, U.C. Berkeley; **bottom left and right:** NASA/JPL/Arizona State University; **p. 22, top:** Jet Propulsion Laboratory; **p. 24, top:** L. November and S. Koutchmy; **p. 26-27:** William K. Hartmann; **p. 28:** Phil Kirchmeier; **p. 29:** Alan Stern, Southwest Research Institute; **p. 30-31:** Phil Kirchmeier; **p. 32-33:** Harold Levison, Southwest Research Institute; **p. 34-35:** J. M. Wrobel and J. E. Conway, National Radio Astronomy Observatory/AUI; **pp. 34-35, bottom:** Steven G. Davis; **pp. 36-39:** NRAO/AUI; **pp. 40-41:** Michael Carroll; **pp. 42-43:** Lee Vande Visse; **p. 44, left:** Luke Dodd; **right:** Charles Alcock, et al./Lawrence Livermore National Laboratory; **p. 45:** Lee Vande Visse; **p. 52:** James Glenn Pearson; **p. 55:** Keith Ward; **p. 57:** John Gleason; **pp. 62-63:** Richard Berry; **p. 62:** Chris Becker; **p. 64:** David Healy; **p. 65:** Jack Newton; **p. 66:** Hal Jandorf; **p. 67:** Richard Berry; **p. 68:** Charles Manion; **pp. 70-71:** Robert Wegner; **pp. 72-73:** Don Davis; **pp. 74-75:** Donald C. Parker; **p. 76:** Steven Davis; **p. 77, left:** Ronald W. Kohl; **p. 77, right:** Richard Berry; **p. 81, top:** Michael Stecker, 14-inch SCT at f/11, hypersensitized Fuji Super HG 400 film, 90-minute exposure on April 16, 1994; **bottom left:** Ronald W. Kohl, 20-inch Cassegrain, STAR I CCD camera, taken on April 8, 1994; **bottom right:** Harvey Freed, 10-inch SCT at f/10, hypersensitized Tech Pan film, 10-minute exposure on March 12, 1994; **p. 82, top left:** Mansfield Clinnick, 8-inch f/4 reflector, Ektar 1000 film, 20-minute exposure on April 4, 1994; **bottom left:** Ronald W. Kohl, 20-inch Cassegrain, STAR I CCD camera, 5-minute exposure on March 12, 1994; **top right:** Alan Dyer, 4-inch f/4.5 refractor, ScotchChrome 400 film, 10-minute exposure on April 1, 1994; **bottom right:** Ronald W. Kohl, 20-inch Cassegrain, STAR I CCD camera, 6-minute exposure on March 1, 1994; **p. 83:** Leo Aerts, 12-inch f/8 reflector, Tech Pan film, 2-second exposure on February 20, 1994 ☐

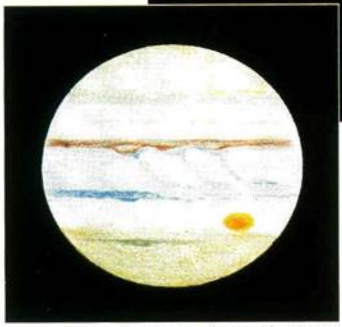
"NO OTHER EYEPIECES...SATISFY ME NOW."

— The following unsolicited letter from a fellow enthusiast is dated Mar. 30, 1994. It is printed unedited and with permission.

Dear Mr. Nagler,

"I thought it long overdue that I write to give my impressions of your Nagler eyepiece designs. *I say 'long overdue,' because I bought my first Nagler (a 7mm) back in 1984. The reason for the purchase was that earlier that year I had invested in a Celestron C-11 and a 4" Fluorite, F/9 refractor. I thought that the stated objectives of the Nagler design — long eye-relief and a wide, highly corrected field of view, would exploit the full potential of a telescope with 2,800mm focal length, and the imaging capacities of a fine refractor. I was not disappointed. Soon after came the fantastic 9mm and 11mm Naglers and then the 4.8mm for the refractor.*

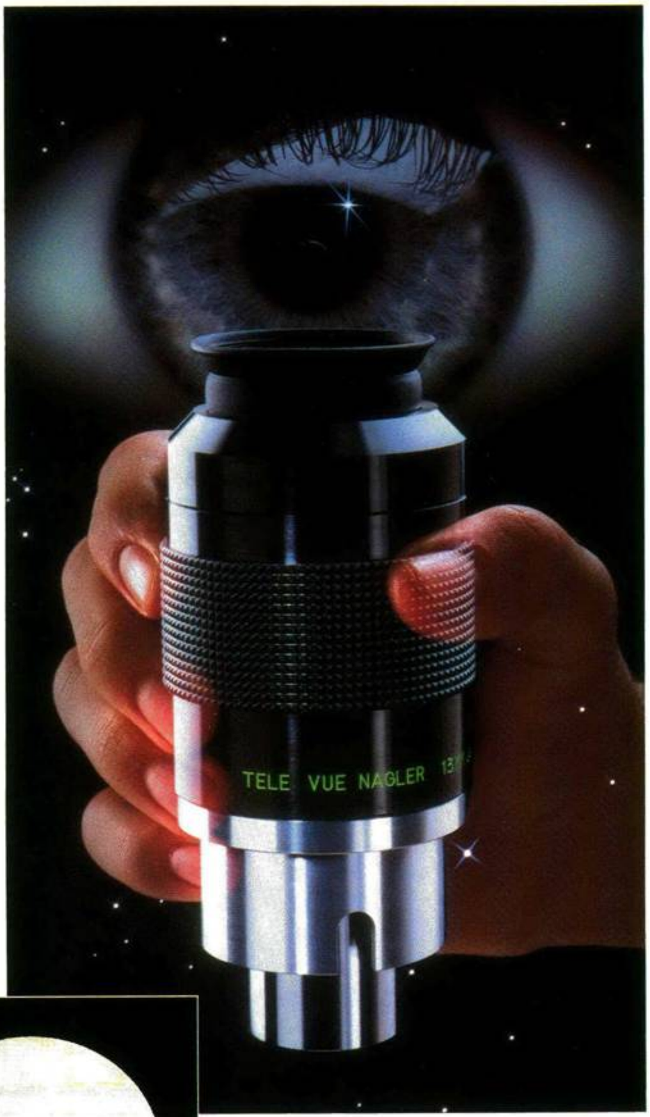
These eyepieces have given me my most rewarding hours spent at the telescope. *My main interest is in the planets which I draw and give lectures on at our local school and observatory. The observation of the planets requires painstaking hours spent at the eyepiece. The Naglers suit my purposes exactly.*



Drawn by Mr. Toohey with 12 N2

When the Type 2s were introduced onto the market I could not resist them. I purchased the 16mm and 12mm models. The 20mm seemed too large, heavy and costly, so I left it alone. These were the same reasons for not buying the 13mm (apart from the fact that by then I owned a 12mm Type 2). However, earlier this year, after years of looking through other people's 13mm and 20mm Naglers, I finally decided to take the plunge myself. ***So now I own a full set of Naglers*** *(including the wonderful 11mm which despite many offers, I will not part with).*

When I remember what eyepieces for the amateur market were like before the introduction of the Naglers (like looking down a drain pipe, or 60° fields, with astigmatism and severe edge of field aberrations), ***it is clear that your designs have taken us a quantum leap forward. No other eyepieces, in the Naglers' range of focal lengths, satisfy me now.***



Many of my fellow planetary observers say that conventional field eyepieces are sufficient. In a way they are right; good Plössls, for example, produce superb images. However, I believe the extra eye-relief, the huge field of the Naglers, coupled with marvellous image correction and the impression that ***the telescope simply gets out of the way,*** *all add up to a delightful psychological difference when using the Naglers. One feels more involved, more present to what one is viewing.*

Over the years I have found that amateur astronomers can be fairly stubbourn people in somehow defending their choice of equipment. Next thing you know they upgrade what was once, in their view, the very best available. ***Only good products stand the test of time. For me, the Naglers are such a product.*** *Not only have they remained with me; I have kept buying more of them!*

To some extent, astronomy, and particularly amateur astronomy, is about emotion and the involvement of the imagination. ***I have to say that Nagler eyepieces have captured my imagination.*** *As well as giving pride of ownership, Naglers are immensely satisfying and a joy to use.*

The little instruction sheet that comes with the eyepieces says that you wish the user 'years of exciting viewing with these eyepieces, and welcome comments on your experiences with them.' So you asked for it. After a decade of superb images (many of which remain etched on my memory; most of which I have recorded on paper) I felt it timely to share my comments and to thank you for your contribution to amateur astronomy."

Yours Sincerely.
Christopher A Toohey

Christopher Toohey, Australia

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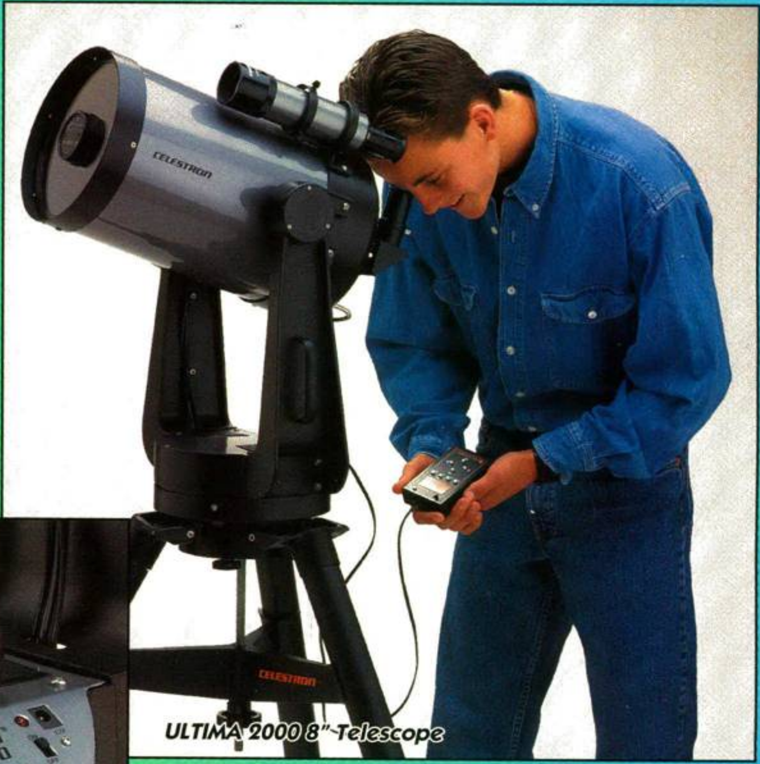

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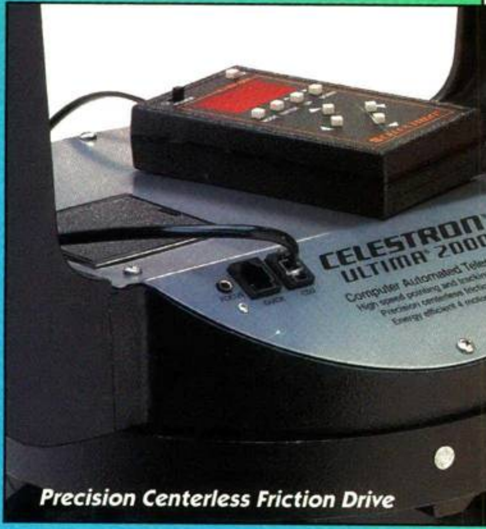
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